

Naval Medical Research Institute  
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**THERMAL PROTECTION AND DIVER PERFORMANCE  
IN SPECIAL OPERATIONS FORCES COMBAT SWIMMERS  
(OVER-THE-BEACH PHASE)**

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## TECHNICAL REVIEW AND APPROVAL

NMRI 98-11

The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

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# REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words)  Special operations requirements often involve mission scenarios in cold environments. Optimal thermal protection is necessary for the successful completion of these missions. This study compared three different thermal protection garments for Naval Special Warfare (NSW) combat swimmers for use in an over-the-beach (OTB) mission scenario. The subjects were 7 U.S. Navy SEAL operators from the NSW Development Group (NSWDG). Each subject participated in a standardized exposure routine 3 times and therefore served as his own control by wearing each of 3 different garment ensembles one time. An extensive market survey conducted by the NSWDG determined the 3 ensembles that were tested:  1) Bare™ dry suit ensemble, 2) Trek™ dry suit ensemble, 3) Typhoon™ dry suit ensemble				
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The standardized exposures consisted of serial wet-dry phases in 38 °F water, 15 °F and -5 °F air (includes wind chill effect) for a total exposure duration of 8 h. The exposure was designed to simulate a NSW boat transit / over-the-beach (OTB) mission. The Special Operations Forces (SOF) Mission-Related Performance Measures (MRPM) was used to evaluate physical and cognitive performance at the midpoint and end of the exposures. The physical battery consisted of tests of manual dexterity, handgrip strength and duration, shooting skills, a step test, and pull-ups. The cognitive battery consisted of the following tests: matching-to-sample, complex reaction time, visual vigilance, serial addition/subtraction, logical reasoning, and repeated acquisition. Heart rate and finger, toe and rectal temperatures were recorded. Performance and temperature data were analyzed to determine which garment ensemble provided the best thermal protection in this simulated operational scenario.

All 3 of the dry suit ensembles adequately protected core body temperatures for the full 8-hour exposure, while hand and foot temperatures were not maintained in an area preferable for NSW operations. Better overall thermal protection was provided by the Bare and Typhoon dry suit ensembles than the Trek dry suit. The Bare and the Typhoon suits also allowed SEALs to perform better on tests of SOF mission-related performance. When asked for a subjective ranking of the best dry suit for OTB missions, all 7 of the NSWDC SEALs chose the Bare dry suit.

The Bare dry suit, with minor modifications, is recommended for use in thermally challenging NSW OTB missions at this time. Further research and development to improve hand and foot thermal protection for similar NSW operations is still necessary.

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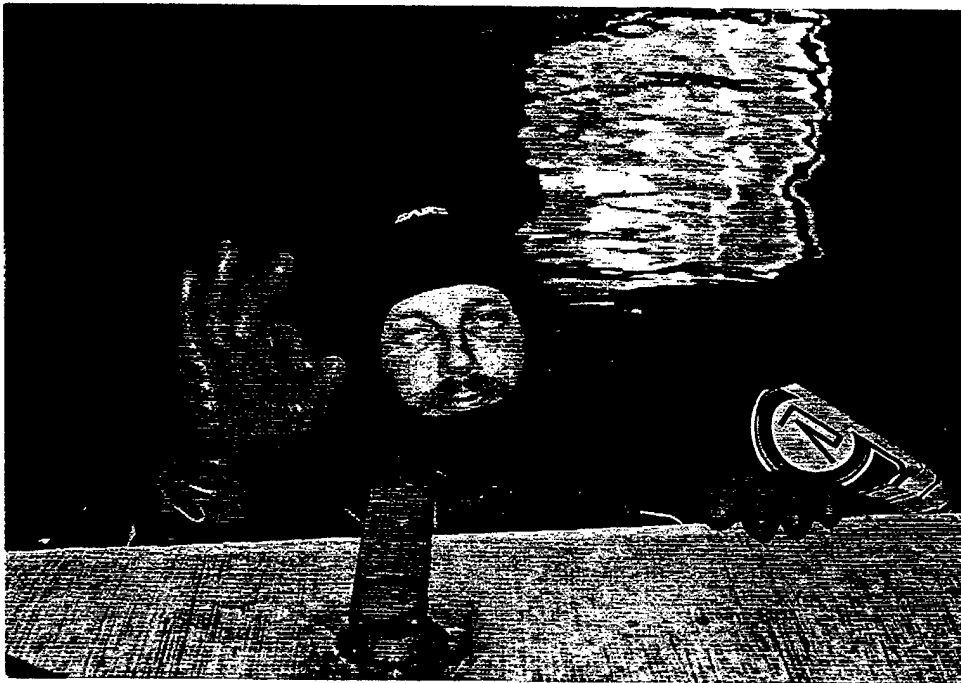
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ENCLOSURE : VHS Videotape - Video Summary of the Study

## DEDICATION

THIS STUDY IS DEDICATED TO THE NAVY FROGMAN – ONE FOOT IN THE COLD WATER AND ONE FOOT OUT – MAY BOTH FEET ALWAYS BE “O.K.”



**Photo 1.** *Navy Frogman giving the traditional “O.K.” sign in the NMRI test pool.*



## **ACKNOWLEDGMENTS**

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The opinions expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government.

The research reported employing human subjects was conducted at the Naval Medical Research Institute (NMRI) and was sanctioned by the Committee for the Protection of Human Subjects at NMRI and at the Naval Medical Research and Development Command.

## **BACKGROUND**

Special Operations Forces (SOF) and combat swimmers are often required to carry out their missions in a cold air / water environment. Successful completion of the mission and the safety of the operator are contingent upon adequate thermal protection. A great variety of thermal protective garments, none of which is clearly superior to another, are commercially available to Naval Special Warfare (NSW) units. Therefore, selecting the best garment for a given mission scenario has traditionally been difficult.

The NSW Development Group (NSWDG) was specifically interested in assessing the thermal protective characteristics of garments currently available for use in thermally challenging over-the-beach (OTB) mission scenarios. The NSWDG collaborated with the Naval Medical Research Institute (NMRI) to identify the relative merits of these garments.

## **OBJECTIVES**

This study aimed to examine a number of thermal protection options for NSW personnel operating in a thermally challenging OTB mission scenario. Specific goals are listed below:

- Identify the particular thermal garments currently in use and alternative garments with potential for use in NSW OTB operations.
- Test the relative efficacy and performance characteristics of the identified thermal protection garments in a simulated thermally challenging OTB mission scenario.

- Make recommendations concerning the relative effectiveness for each thermal garment.

## **METHODS**

United States Navy SEALs from the NSWDG conducted an extensive survey to identify the dry suit ensembles (to include thermal undergarments) with the best potential for use in an OTB mission profile. NSWDG began their research by surveying key command personnel to identify dry suit specifications and essential features for NSW operations. In addition, NSW Groups 1 and 2, and the Coast Guard were contacted to identify their current ensembles and discuss dry suits under consideration for future acquisition. Numerous manufacturers and distributors were contacted to establish baseline information on suit materials, styles, configurations, options, design features, accessories, and cost. Follow on market research was conducted during attendance at the 1997 DEMA trade show.

Published thermal protection studies were reviewed. Research relevant to the intended application was validated for currency and accuracy. Final reviews of the dry suits were conducted at NMRI, Bethesda, MD, and NEDU, Panama City, FL.

### ***Suits Considered But Not Selected***

#### **DUI Coast Guard Rescue Swimmer TLS**

1) **Description:** Trilaminate diagonal zip style front entry with latex neck and wrist seals, and relief zipper. Legs terminated in lightweight closed-cell neoprene with a hard Vibram™ sole.

2) Comments: Although relatively lightweight, the suit design allowed for excessive lower torso material. The adjustable through-the-crotch torso strap was inadequate for managing the excess suit material. The neoprene boot provided minimal protection, no support, and did not incorporate fin strap retainers.

#### Viking Pro 1000 Surveyor

1) Description: Vulcanized rubber rear entry with latex neck and wrist seals, integral latex hood, and integral boots.

2) Comments: Vulcanized rubber material caused increased suit weight. The suit was not form fitting.

#### Typhoon Pro

1) Description: Trilaminar bib style front entry with rigid neck and wrist rings (and corresponding latex seals), and integral boots.

2) Comments: Rigid rings were bulky and cumbersome (increased potential for catching on objects). The integral boots were not designed specifically for dry suit applications, but were merely an adapted fire-fighting boot. The boot did not provide adequate support or stability.

#### Diamond Saxon

1) Description: Trilaminar diagonal zip style front entry with integral boot.

2) Comments: These suits were previously evaluated by the NSWDC. The workmanship and performance of the suit was assessed as inadequate. The integral boots were not designed specifically for dry suit applications, but were merely an adapted fire-fighting boot. The boot did not provide adequate support or stability.

### Poseidon Unisuit

1) Description: 7-mm neoprene front entry suit, with neoprene neck and wrist seals, and an integral neoprene sock.

2) Comments: Neoprene material caused increased suit weight. Lack of integral boots. Concern over the excessive zipper length.

The three dry suit ensembles that were selected for testing and the manner in which they were worn in this study are summarized below.

## ***Dry Suit Ensembles Selected***

---

**TEST ENSEMBLE # 1 (BARE) - Fitzwright Co. Ltd**  
5760 Production Way  
Langley, British Columbia  
Canada, V3A 4N4  
  
604-533-7848 or 800-663-0111

- **Outerwear:**

- Bare Trilaminate Commercial Dry suit
  - Front Entry
  - 3-mm Neoprene Neck Seal and Latex Wrist Seal
  - Relief Zipper
  - Integral Lower Leg Gaiter
  - Insulated Integral Neoprene Boot
- DUI Dry-5 Glove (DUI / Diving Unlimited International; 800-325-8439)
- Bare Dry Hood - 7-mm closed-cell neoprene
- Supplemental Outerwear (worn during the dry phases of the study)
  - Outdoor Research Gorilla Balaclava - Windstopper Fleece (Outdoor Research; 800-421-2421)
  - Black Diamond All-Conditions GTX Leather-Palm 5-finger Glove (Black Diamond Equip. Ltd.; 801-278-5533)

- **Underwear.**

- **1<sup>st</sup> Layer:**
  - Patagonia Capilene Underwear (top and bottom) (Patagonia; 800-638-6464)
  - Sock System:
    - Thorlo Ski Sock Liner
    - Fox River Mills "Attitude" Sock
  - Lifa Glove Inserts
- **2<sup>nd</sup> Layer:**
  - Bare Polar Extreme Underware – M200 Thinsulate™



**Photo 2.** Bare Polar Extreme Underwear



**Photo 3.** Bare Trilaminate dry suit.



**TEST ENSEMBLE # 2 (TREK) - Trelleborg Beadle Unit 30, Bergen Way  
Sutton Fields Industrial Estate  
Hull, United Kingdom, HU7 0YQ**

**011-44-1-482-839-119**

- **Outerwear:**

- Amron Trek Dry suit
  - Polyurethane
  - Latex Neck and Wrist Seals
  - Relief Zipper
  - Non-Insulated Integral Boot
- Attachable 5-Finger Dry Glove
  - With inner and outer ring system
- Bare Dry Hood - 7-mm closed-cell neoprene
- Supplemental Outerwear (worn during the dry phases of the study):
  - Outdoor Research (OR) Gorilla Balaclava - Windstopper Fleece
  - Black Diamond All-Conditions GTX Leather-Palm 5-finger Glove

- **Underwear.**

- **1<sup>st</sup> Layer:**
  - Patagonia Capilene Underwear (top & bottom)
  - Fox River Therm-a-Wick Liner Sock
  - Outdoor Research (OR) Liner Gloves - Windstopper Fleece
- **2<sup>nd</sup> Layer:**
  - Amron Seafarer Jumpsuit - 28 ounce fleece (Amron International Diving Supply, Inc.; Escondido, CA)
  - Amron Seafarer Undergarment Boot - 28-ounce fleece



**Photo 4.** Amron Seafarer Jumpsuit with boots.



**Photo 5.** Trek polyurethane dry suit.

<b>TEST ENSEMBLE # 3 (TYPHOON) - Typhoon Internat'l Limited</b> <b>Mortlake Court, 28 Sheen Lane, East Sheen</b> <b>London, England, SW14 8LW</b>  <b>011-44-1-818-769-818</b>
--

- **Outerwear:**

- Typhoon Ranger II Dry suit
  - Trilaminate
  - Latex Neck and Wrist Seals
  - Relief Zipper
  - Insulated (Neoprene) Integral Boot (Thermic)
- DUI Dry-5 Glove
- Bare Dry Hood - 7-mm closed-cell neoprene
- Supplemental Outerwear (worn during the dry phases of the study):
  - Outdoor Research (OR) Balaclava - Windstopper Fleece
  - Black Diamond All-Conditions GTX Leather-Palm 5-finger Glove

- **Underwear.**

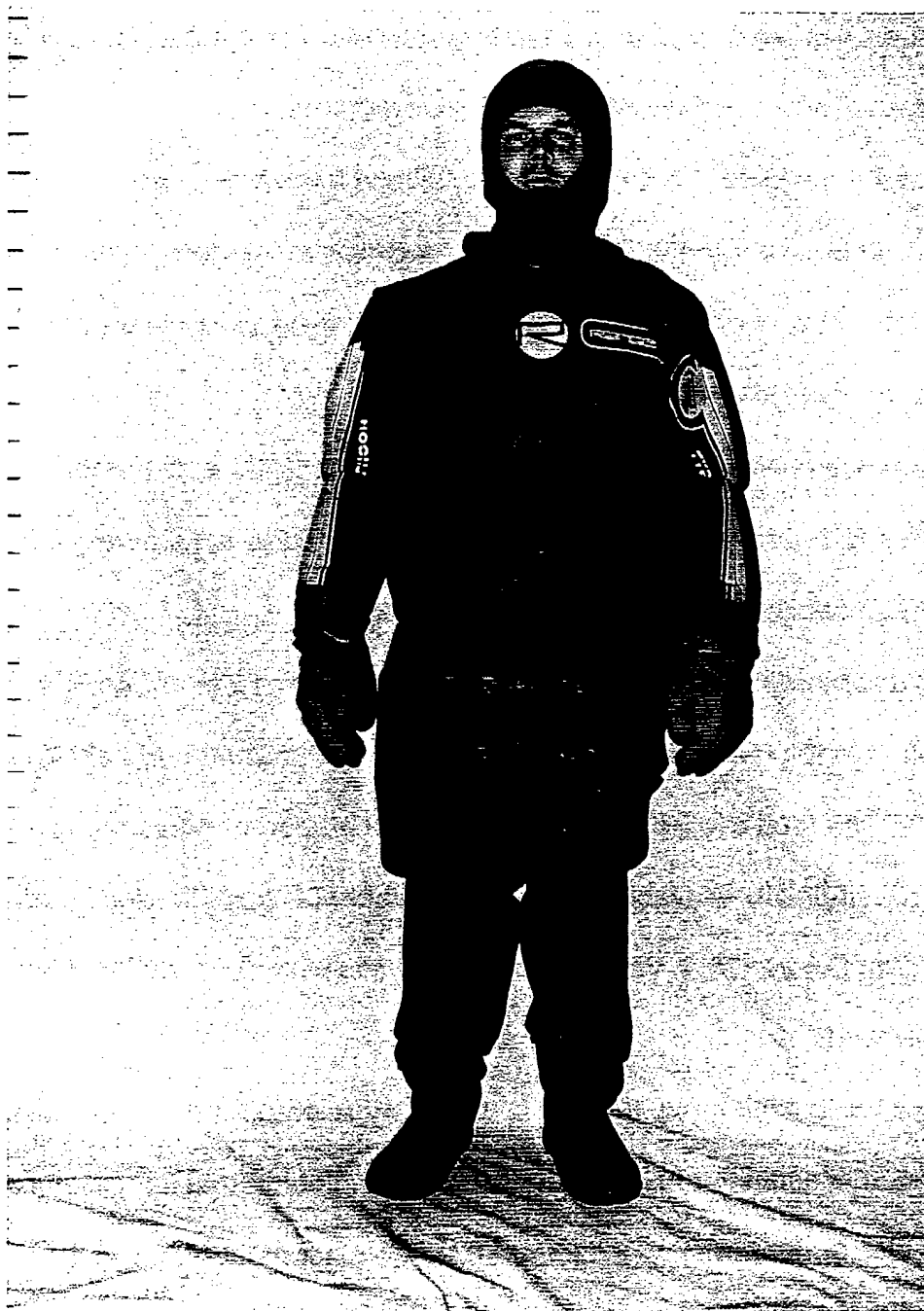
- **1<sup>st</sup> Layer:**
  - Patagonia Capilene Underwear (top & bottom)
  - Fox River Therm-a-Wick Liner Sock
  - Lifa Glove Inserts
- **2<sup>nd</sup> Layer:**
  - Andies Undersuit – M200 Thinsulate™
  - Andies Undergarment Sock – M200 Thinsulate™

Additional equipment used at various points during the study:

- Fins
- Goggles
- Dive Mask
- Load Bearing Equipment (LBE) - full canteens, weight simulating loadout



**Photo 6.** Andies Undersuit and Andies undergarment sock.



**Photo 7.** Typhoon Ranger II Trilaminate dry suit.

This study was conducted with 7 healthy volunteer male subjects. All were members of the NSW DG and experienced SEAL operators.

None of the subjects had a history of significant thermoregulatory problems, which would include hypothermia that required medical intervention, frostbite, non-freezing cold injury (i.e., trenchfoot), chilblains, or heat exhaustion/stroke. All subjects gave informed consent to participate in this study.

All subjects were required to abstain from alcohol, nicotine, caffeine, and strenuous exercise for 12 h prior to the dive. They were instructed to eat a hearty dinner and get a good night's sleep the day before the dive.

During a subject's first exposure routine, he was allowed to eat and drink at his own discretion. On the next 2 exposure routines, he was prompted to eat and drink a similar amount. The food available consisted of either standard meals ready-to-eat (MREs) or a commercially available complex carbohydrate "syrup" called "Carb-boom" (Carb-Boom; San Diego, CA ). Water was the only available fluid. No hot meals or hot drinks were allowed.

During all cold exposures, the divers were instrumented with a thermistor placed 15 cm past the anal sphincter for continuous monitoring of internal temperature.

Finger skin temperature was measured by the placement of a skin thermistor on the palmar aspect of the distal tip of the middle finger during all cold exposures. Toe skin temperature was measured by the placement of a skin thermistor on the dorsal aspect of the distal tip of the second toe during all cold exposures.

Electrode pads were placed on the diver's chest in a three-lead electrocardiogram configuration. Heart rate and rhythm were monitored continuously during all exposures.

Urine output was collected and quantified during each cold exposure.

The exposure routine was developed by the NSW DG and is based on a typical cold-weather NSW OTB mission scenario. The entire exposure was 8 h long and involved cold in-water phases and cold air phases, with alternating periods of exercise and rest. The following is the exact exposure routine followed for each of the cold exposures:

### ***Standardized Exposure Routine***

#### **PHASE 1: PRE-EXPOSURE**

All subjects performed the following:

- Staged individual physical training (P.T.) gear, load bearing equipment (LBE), supplemental protective equipment, and food and water.
  - Instrumented with medical monitoring equipment.
  - Donned dry suit ensembles.
- ⇒ Throughout the exposure, tenders ensured that each subject transitioned to the next phase based on his individual exposure time in each phase.

#### **PHASE 2: POOL EXPOSURE - SIMULATED WET INSERTION**

##### **Controls**

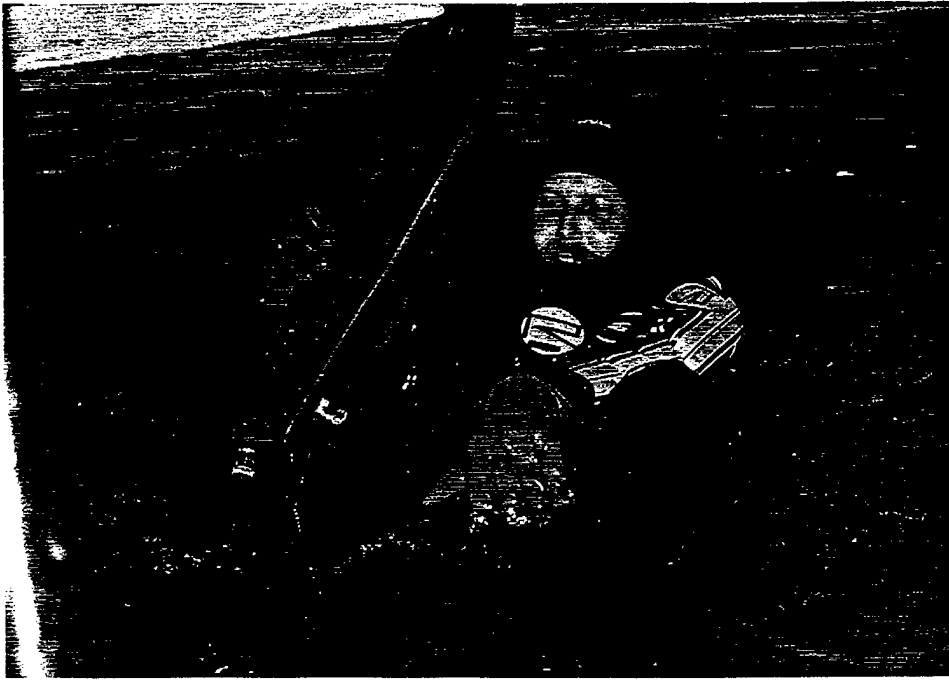
- Water temperature: 3 °C (38 °F)
- Exposure time: 35 min
- A target exercise heartrate was established for each subject based upon his turtlebacking style at a "moderate" pace, and was subsequently kept relatively constant during all turtlebacking phases.



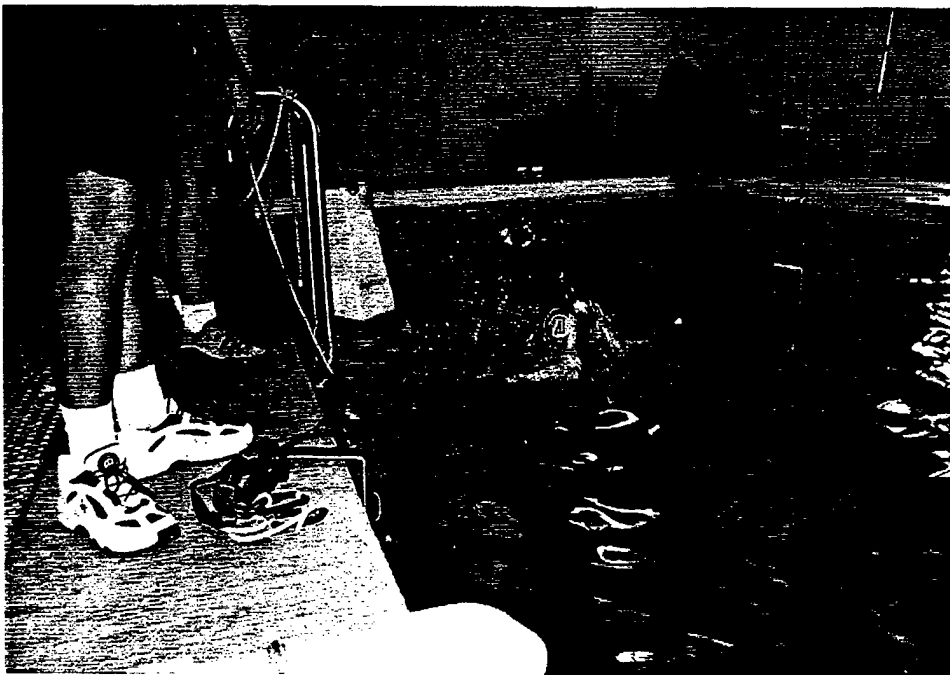
### **Tasks / Exercise**

All subjects performed the following:

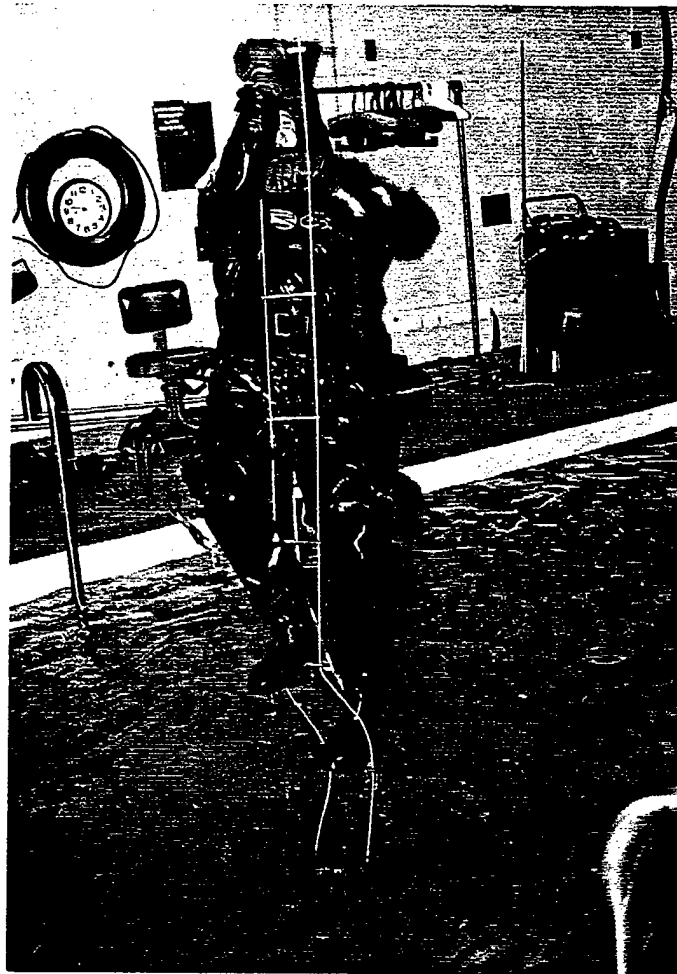
- At ~ 5-minute intervals, entered the pool and *then* donned fins.
- Moved to the pool ladder, donned face mask, and conducted two breath hold descents to the pool bottom (~15 fsw). Descents were assisted with a tethered weight belt.
- Moved to a predetermined point, hooked-up to a tension sling, and turtlebacked for 15 min (moderate activity).
- Remained stationary for 10 min with hands in the water and head out.
- When directed, doffed fins and climbed a caving ladder (a portable / roll-up ladder made of wire lines that hold ~ 6 inch metal rungs) four times (~ 10 ft per single climb or 40 ft overall). The ladder was suspended from a beam across the roof ~ 10 ft directly above the pool. (This task was deleted after the first 2 days of testing when it was determined that all of the suits would require additional reinforcement in the crotch/inner thighs).
- Exited the pool and transitioned to the environmental chamber.



**Photo 8.** Phase 2 – Donning Fins.



**Photo 9.** Phase 2 - Breath-hold descent to 15 fsw.



**Photo 10.** Phase 2 – Caving ladder climb.

**PHASE 3: ENVIRONMENTAL CHAMBER EXPOSURE - SIMULATED BOAT TRANSIT**

**Controls**

- Ambient air temperature: -10 °C (15 °F)
- Wind speed: 12 mph
- Wind Chill Effect: -21 °C (-5 °F)
- Exposure time: 2 h
- Subjects were prompted to consume food during this phase.

## Tasks / Exercise

All subjects performed the following:

- Entered the environmental chamber and donned supplemental protective equipment:
  - Head Gear (Outdoor Research balaclava)
  - Eye Protection - Goggles
  - Black Diamond 5-finger gloves
- Stood stationary on a commercial ski trainer / exercise machine positioned directly in front of the fan for 2 h. Later in the exposure the subjects exercised on the ski trainer, but initially it was used to properly position the subjects in front of the fan.
- Upon completion, doffed supplemental protective equipment, restored ensemble to the swimming configuration, donned LBE, and transitioned to the pool.

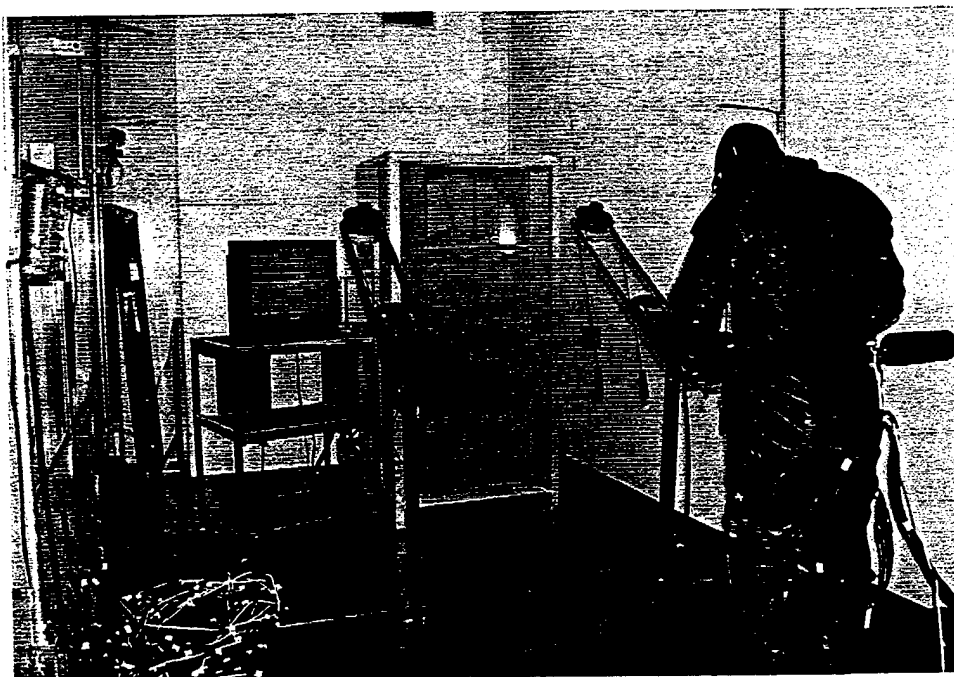


Photo 11. Phase 3 – Simulated Boat Transit in environmental chamber with fan.

## PHASE 4: POOL EXPOSURE - SIMULATED TURTLEBACKING

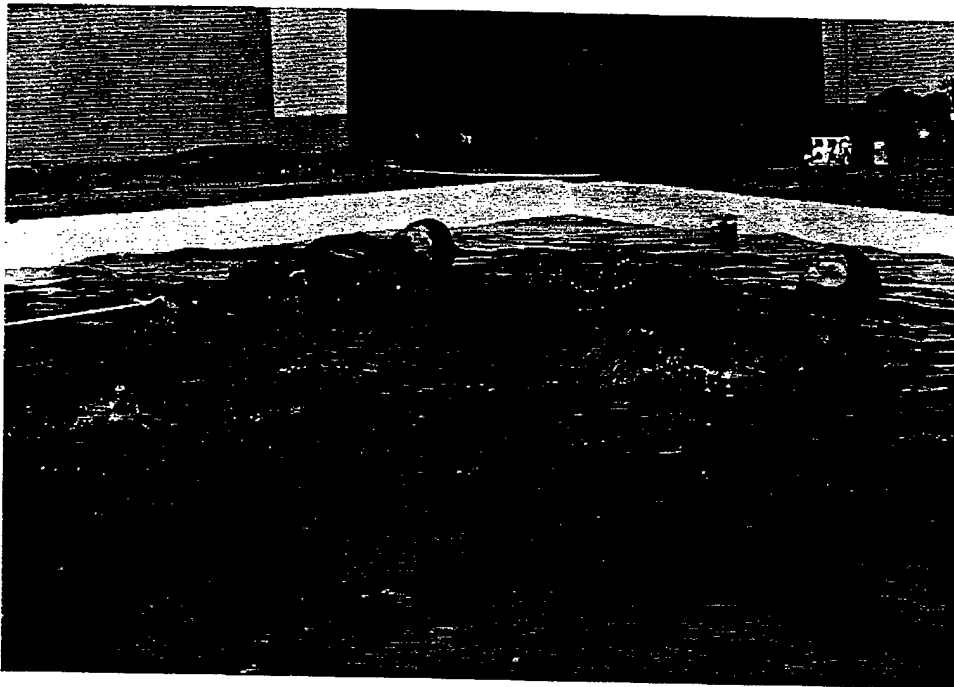
### Controls

- Water temperature: 3 °C (38 °F)
- Exposure time: 2 h 20 min

### Tasks / Exercise

All subjects performed the following:

- Donned fins and ankle weights, then entered the pool and hooked-up to assigned tension sling.
- Turtlebacked for 60 min (moderate activity).
- Remained stationary for 40 min with hands in the water and head out.
- Turtleback for 40 min (moderate activity).
- Upon completion, exited the pool, and transitioned to the 1<sup>ST</sup> SOF Mission-Related Performance Measures (MRPM) station.



**Photo 12.** Phase 4 – Simulated turtlebacking in pool with tension-sling.

## **PHASE 5: EXPOSURE CESSATION - CONDUCT PARTIAL SOF MRPM TESTS**

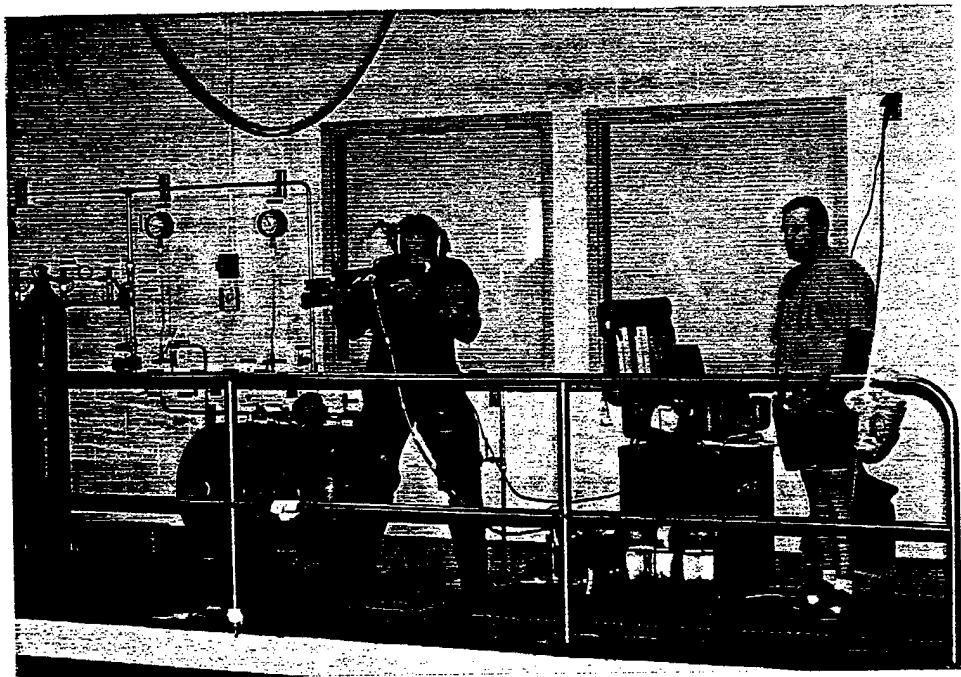
### **Controls**

- Ambient Air temperature: 20 °C (68 °F)
- Maximum time of exposure: 15 min

### **Tasks / Exercise**

All subjects performed the following:

- Remained dressed-out with the exception of hand and headgear.
- Conducted the following physical SOF MRPM tests:
  - Manual Dexterity - disassemble/reassemble weapon (M4).
  - Grip Strength - hand dynamometer
  - Marksmanship/Shooting - laser weapon system
- Upon completion of SOF MRPM, each subject transitioned to the chamber.



**Photo 13.** Phase 5 – MRPM – Test of Marksmanship.

## **PHASE 6: ENVIRONMENTAL CHAMBER EXPOSURE - SIMULATED PATROLLING**

### **Controls**

- Ambient Air Temperature: -10 °C (15 °F)
- Exposure time: 1 h 30 min
- A target exercise heartrate was established for each subject based upon his skiing style at a "moderate" pace, and was subsequently kept relatively constant during all skiing phases.
- Subjects were prompted to consume food during this phase.

### **Tasks / Exercise**

All subjects performed the following:

- Entered the chamber and donned supplemental protective equipment:
  - Head Gear (Outdoor Research Balaclava)
  - Black Diamond 5-finger gloves
- Exercise Circuit:
  - Sat in a chair for 30 min and conducted cognitive portion of SOF MRPM
  - Mounted ski trainer and skied for 20 min (moderate activity).
  - Resumed seated position for 10 min (minimal movement).
  - Mount ski trainer and skied for 20 min (moderate activity).
  - Resumed seated position for 10 min (minimal movement).
- Upon completion, doffed supplemental protective equipment, restored ensemble to the swimming configuration and transitioned to the pool.



**Photo 14.** Phase 6 – Simulated Patrolling on ski-trainers.



## PHASE 7: POOL EXPOSURE - SIMULATED SHORT TURTLEBACK

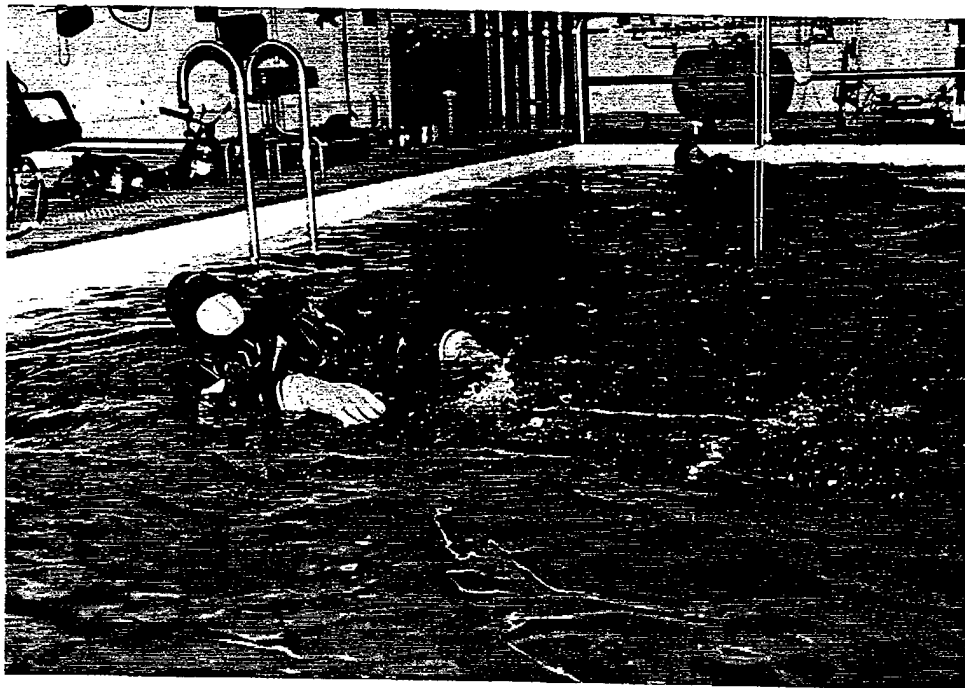
### Controls

- Water temperature: 3 °C (38 °F)
- Exposure time: 15 min

### Tasks / Exercise

All subjects performed the following:

- Donned fins and ankle weights, then entered the pool.
- Turtlebacked for 15 min (moderate activity).
- Upon completion, exited the pool, and transitioned to the chamber.



**Photo 15.** Phase 7 – Simulated turtlebacking

## **PHASE 8: ENVIRONMENTAL CHAMBER EXPOSURE - SIMULATED BOAT TRANSIT**

### **Controls**

- Ambient air temperature: -10 °C (15 °F)
- Wind speed: 12 mph
- Wind Chill Effect: -21 °C (-5 °F)
- Exposure time: 1 h 20 min
- Subjects were prompted to consume food during this phase.

### **Tasks / Exercise**

All subjects performed the following:

- Entered the chamber; doffed LBE and donned supplemental protective equipment:
  - Head Gear (Outdoor Research balaclava)
  - Eye Protection - Goggles
  - Black Diamond 5-finger gloves
- Sat in a chair for 30 min and conducted cognitive portion of SOF MRPM.
- Stood stationary on ski trainer positioned directly in front of the fan for 50 min.
- Upon direction, exited the chamber.



**Photo 16.** Phase 8 – Simulated Boat Transit

## PHASE 9: POST EXPOSURE - CONDUCT COMPLETE SOF MRPM TESTS

All subjects performed the following:

- Doffed gloves and headgear and conducted the following SOF MRPM tests:
  - Manual Dexterity - disassemble/reassemble weapon (M4).
  - Grip Strength - hand dynamometer
  - Marksmanship/Shooting - laser weapon system
- Doffed dry suit ensemble, donned PT gear, and conducted remaining SOF MRPM tests:
  - Step test
  - Pull-ups
- Completed dry suit questionnaire.



**Photo 17.** Phase 9 – MRPM Test of Manual Dexterity.

Each subject performed this exposure routine once in each of the three suits. The suits were worn in a random order. From measurements of the subject's thermal status, performance tests, and subjective evaluations, comparisons were made concerning the different thermal protective garments.

This study design favors a comparison of thermal garments because each diver served as his own control, thus greatly reducing the differences due to individual variability.

The exposure ended when one of the following criteria were met:

- The subject completed the 8-hour exposure.
- The diver desired to end the dive for any reason.
- The rectal temperature fell to 35 °C and remained there for 1 min (the upper limit of clinical mild hypothermia (1-3); most sources list 33-35 °C as the limits of mild hypothermia), 35 °C is the commonly accepted lower limit for cold exposure studies (4-7).
- Any hand or foot temperature fell below 8 °C and remained there for a period of 30 min, or fell below 6 °C at any time. This termination criteria was set to prevent non – freezing cold injury (NFCI) (8-10). If these criteria were close to being met, the subject was allowed to end that phase of the exposure routine early and move on to the next phase. However, if any of the above criteria were reached, then the exposure routine was terminated.
- Cardiac arrhythmia occurred, or if a heart rate of less than 40 beats per minute (bpm) or greater than 160 beats per min occurred. The reason for this measure was to avoid cold-induced arrhythmia.

There was a minimum of 24 h between exposures for each subject.

### ***Performance Measures***

This research study focused on performance as a comparative means of evaluating the thermal garments. The performance measurement system utilized was the SOF Mission-Related Performance Measures (MRPM) (dry/land-based performance tests of SOF mission-related tasks).

## **SOF MRPM**

The SOF MRPM was developed by NMRI in response to a U.S. Special Operations Command (USSOCOM) tasking to standardize performance measures used in USSOCOM-sponsored research (11,12). This battery of tests was designed to reflect SOF mission-related performance.

The SOF MRPM consists of 5 physical tests and 6 cognitive tests designed to evaluate SOF mission-related tasks. Multiple baseline tests were done first during the work-up phase when the divers were well rested and not under thermally stressful conditions. They were then performed by each subject as outlined in the exposure routine.

The 5 physical tests evaluated strength, endurance, fine and gross motor skills, eye-hand coordination, and vision. The tests are listed below:

1. **Manual Dexterity**: This task is designed to evaluate fine and gross motor skills of the fingers, hands, and arms. Subjects are required to disassemble and reassemble a weapon with which they are familiar (either an M-16 carbine or an HK-MP5 submachine gun).



**Photo 18.** MRPM test of Manual Dexterity – Disassembly & reassembly of a weapon.

2. Maximal Handgrip Strength and Endurance: In this task a hand dynamometer is used to evaluate hand and forearm muscular strength and endurance.



**Photo 19.** MRPM test of handgrip strength and endurance.

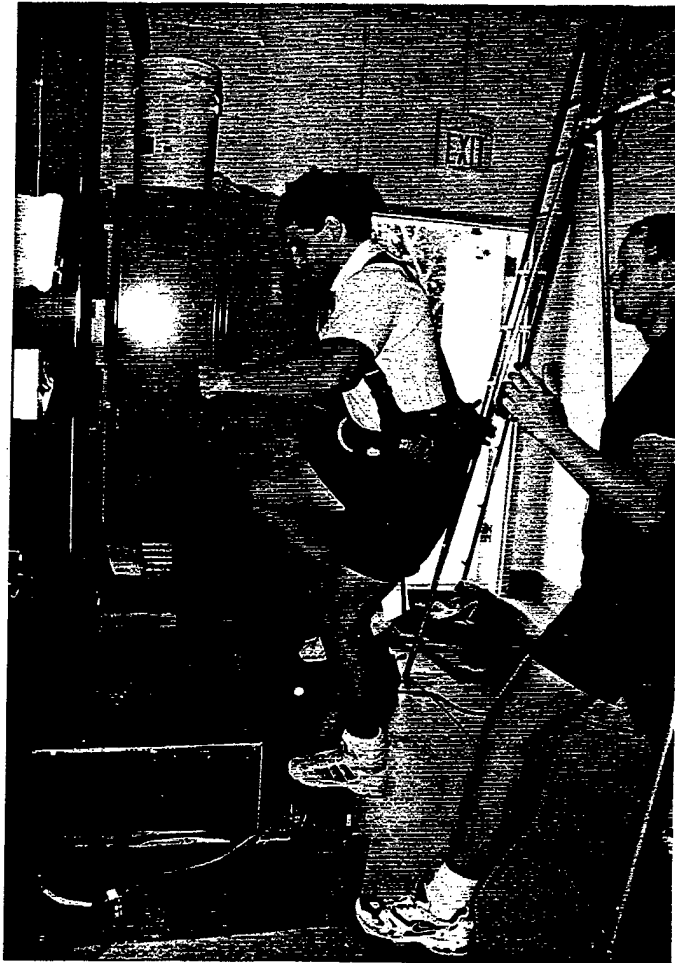


3. Upper Body Strength: This task quantifies strength during a high-intensity exercise for a combination of muscle groups in the upper body by having individuals perform the maximum number of pull-ups on a portable pull-up apparatus.



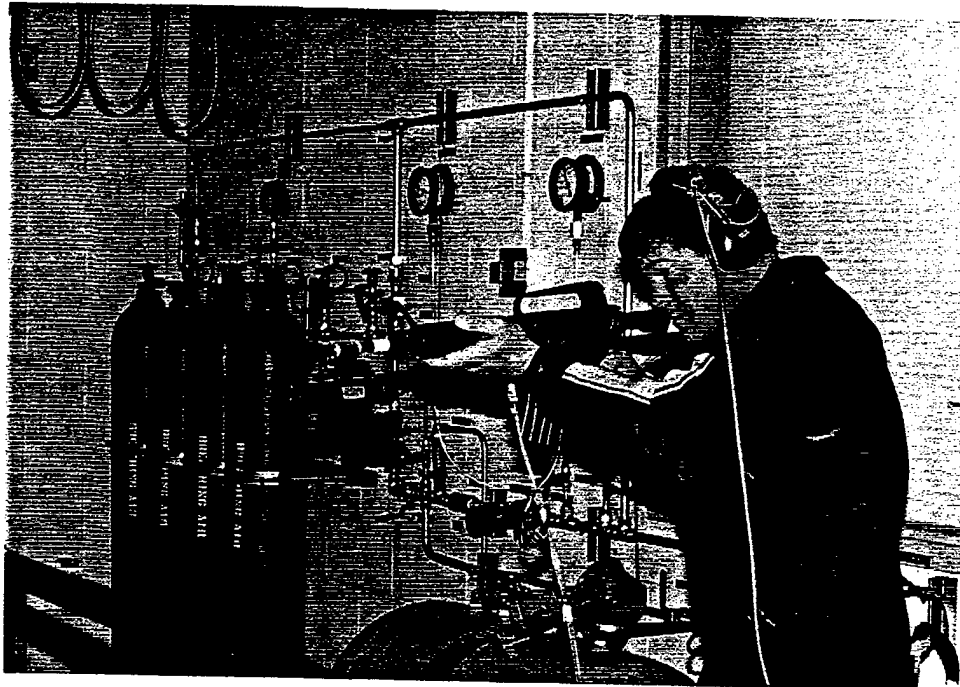
**Photo 20.** MRPM test of upper body strength – Pull-ups.

4. Lower Body Strength, Mobility, and Coordination: In this task individuals wearing a 20-kg weight harness are required to climb and dismount a set of portable steps as rapidly as possible for 1 min.



**Photo 21.** MRPM test of lower body strength – 1-minute Step Test with 20-kg weight belt.

5. Shooting Skills: Specially modified weapons are used to assess the ability of individuals to quickly acquire and hit a series of randomly appearing targets. Weapons have been modified to operate pneumatically using a portable pressurized gas system in a semi-automatic mode. Modifications include a laser system activated by the trigger pull of the weapon and reflective targets that record data using a laptop computer system.



**Photo 22.** MRPM test of marksmanship.

Based on consultation with NSWDC, target sequences (50 presentations per sequence) were specially constructed in an attempt to more accurately reflect mission requirements. Multiple target sequences were constructed in order to avoid repeating a presentation order with any one operator throughout the course of the study. Shooting skills were evaluated by three different methods:

- 1) The number of targets hit vs. the number of targets presented.
- 2) The number of hits on rapidly presented targets. Fifty percent of the targets in any sequence were presented after a 1-second interval from the previous target presentation (represented as % Hits/1 s). The remaining targets were consistently divided between 2- and 3-second intervals between target presentations.
- 3) The average time that it took the shooter to hit the target (represented as Av Time/Hit).

The physical measures of performance were designed to require minimal training prior to baseline data collection. Completion of the physical battery required approximately 10-15 min for each individual. Individuals were required to complete at least two sessions of the physical performance tasks to be used as baseline values. Tests that demonstrated a lack of consistency in the results were repeated. The sequence of testing was consistent between baseline, mid-exposure and post-exposure testing.

The 6 cognitive tasks are listed below in the order in which they were presented on the computer during each session.

### TEST

- 1) Matching-to-Sample
- 2) Complex Reaction Time
- 3) Visual Vigilance
- 4) Serial Addition/Subtraction
- 5) Logical Reasoning
- 6) Repeated Acquisition

### ABILITY TESTED

- to perform tests of short-term memory
- respond to multiple-choice problems
- to sustain mental concentration
- to perform simple mathematical calculations
- to reason
- to learn, or decode a new sequence

### ***Statistical Analysis***

The statistical method utilized to analyze the data was an analysis of variance with repeated measures. The suit type was considered the repeated measure.

Differences between suits were evaluated for significance ( $p < .05$ ) by the Neuman-Kuel's test. The SOF MRPM physical data was analyzed with a two-tailed t-test.

## RESULTS

### *Thermal Data*

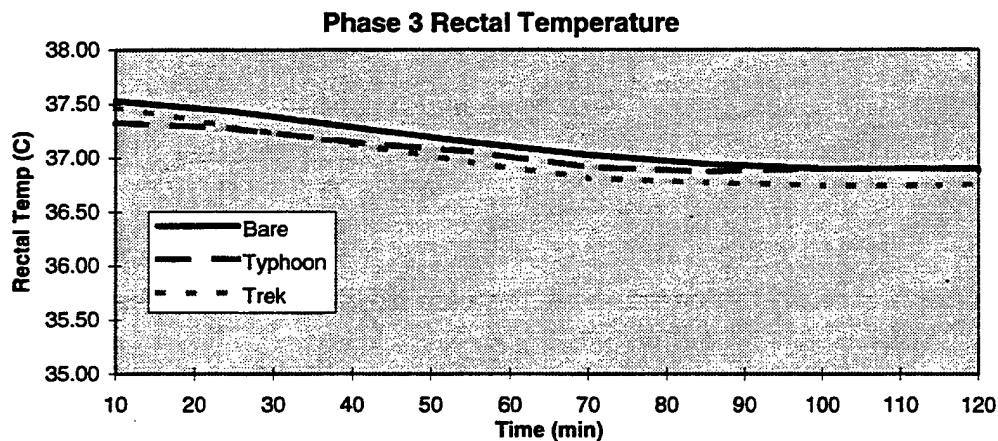
The thermal data is divided into 3 sections: rectal, toe, and finger temperature.

Each section further divides the analysis into the 4 major phases of the study:

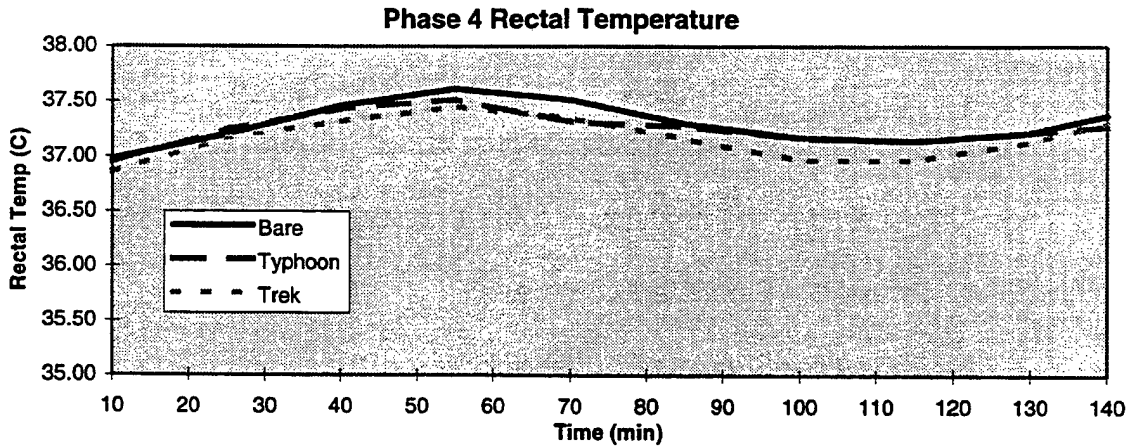
1. Phase 3 – Simulated boat transit
2. Phase 4 – Simulated turtlebacking
3. Phase 6 – Simulated patrolling
4. Phase 8 – Simulated boat transit

### *Rectal Temperature*

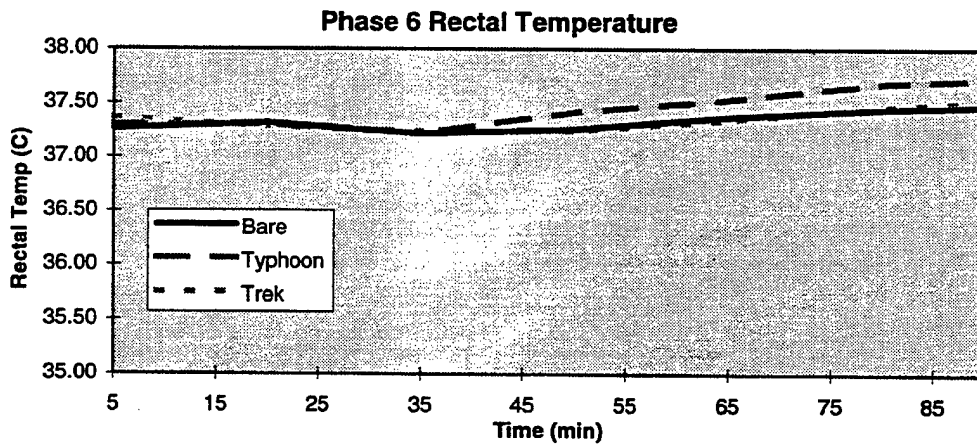
A trend of the rectal temperatures by the 4 major phases of the study are shown in Figures 1 - 4.



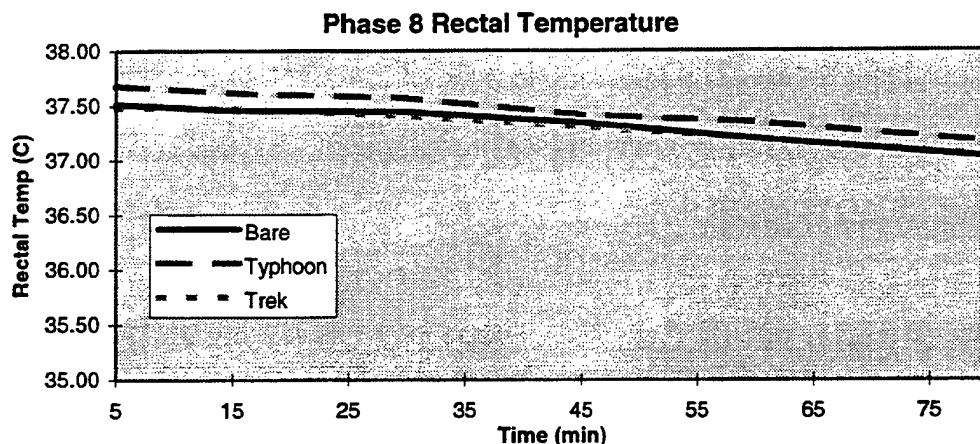
**Figure 1.** Graph of rectal temperature vs. time for each dry suit ensemble during Phase 3 (Simulated Boat Transit).



**Figure 2.** Graph of rectal temperature vs. time for each dry suit ensemble during Phase 4 (Simulated Turtlebacking).



**Figure 3.** Graph of rectal temperature vs. time for each dry suit ensemble during Phase 6 (Simulated Patrolling).



**Figure 4.** Graph of rectal temperature vs. time for each dry suit ensemble during Phase 8 (Simulated Boat Transit).

Very little difference was observed in rectal temperature. None of the divers approached a hypothermic ( $< 35^{\circ}\text{C}$  or  $95^{\circ}\text{F}$ ) rectal temperature, which would have required removal from the exposure. Rectal temperatures did increase an average of  $0.5^{\circ}\text{C}$  with moderate exercise, as seen in Phases 4 and 6.

### ***Finger And Toe Temperatures***

There were significant differences in hand and foot temperatures in this study. None of the suits maintained hand and foot temperatures in a range preferable for NSW operations.

On numerous occasions, hand and foot temperatures approached the termination criteria of the study. In some cases these criteria were reached ( $< 8.0^{\circ}\text{C}$  for a 30-minute period or  $< 6.0^{\circ}\text{C}$  at any time). At this temperature, an extremity is painfully cold, almost always has accompanying decrements in performance, and represents a situation not preferable for NSW operations.



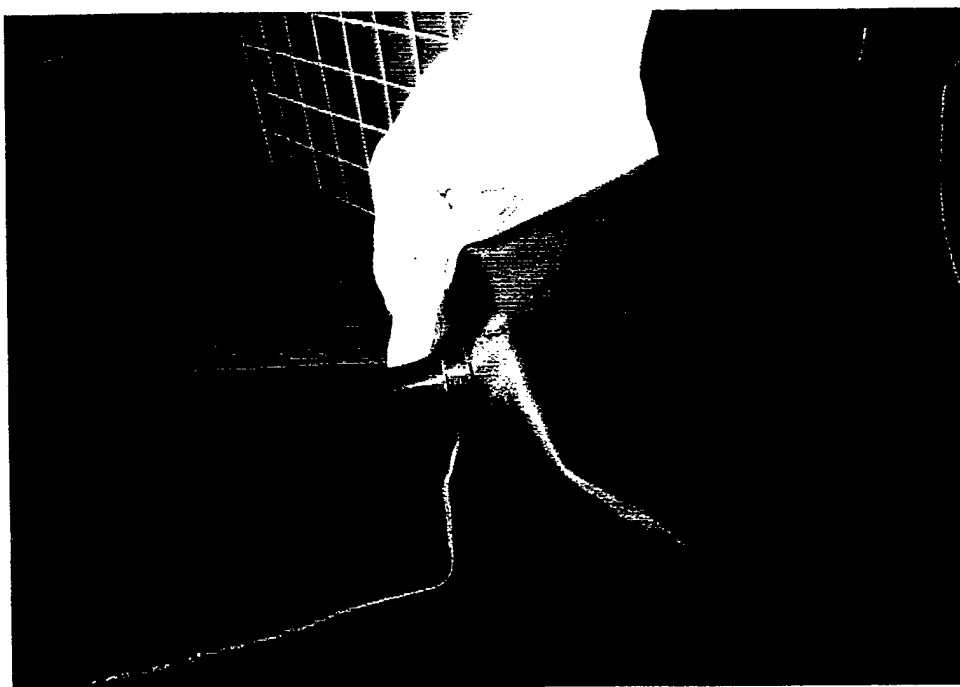
We considered the inability to provide minimal thermal protection for the extremities a point of suit failure. The following is a list of the suit failures, the subject and extremity affected, the phase in which the failure occurred, and the action taken within the parameters of the study.

**TABLE 1. SUIT FAILURES IN THERMAL PROTECTION OF AN EXTREMITY**  
(Hand or foot temperature at 8 °C)

<u>SUIT TYPE</u>	<u>SUBJECT/EXTREMITY</u>	<u>STUDY PHASE</u>	<u>ACTION TAKEN</u>
Trek	A / Foot	3	Removed 45 min early from phase 3
Trek	A / Hand	4	Exposure terminated 25 min into phase 4
Trek	B / Foot	3	Removed 35 min early from phase 3 - remainder of exposure completed
Trek	G / Foot	3	Removed 35 min early from phase 3 - remainder of exposure completed
Trek*	C/Foot	4	Exposure terminated at the end of Phase 4.
Typhoon	A / Foot	8	Exposure terminated 35 min early

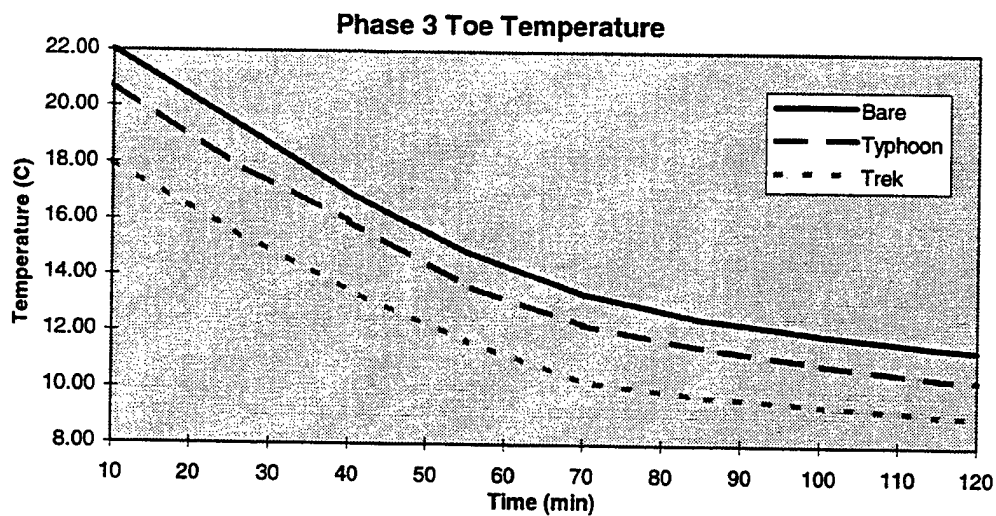
*Note: \*This brand new Trek Suit got a small tear in the crotch during this exposure. The tear occurred during the caving ladder climb and subsequently caused the suit to slowly flood out. This caused the subject's toe temperature to reach the abort criteria. The photo below shows the small tear in the suit. No other suit tore during this study.*

The Bare dry suit ensemble provided minimal thermal protection for the extremities, and had no suit failures.

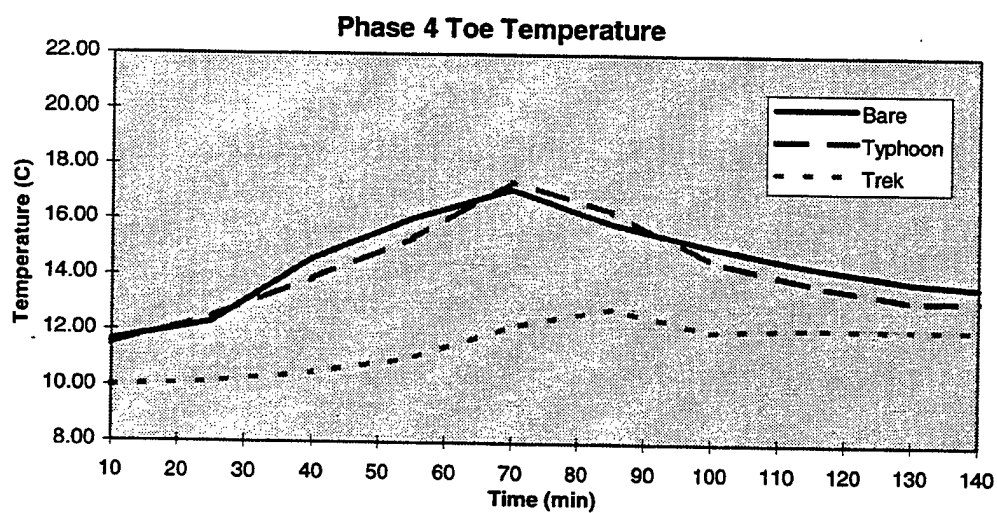


**Photo 23.** Small tear in crotch of TREK dry suit from caving ladder climb.

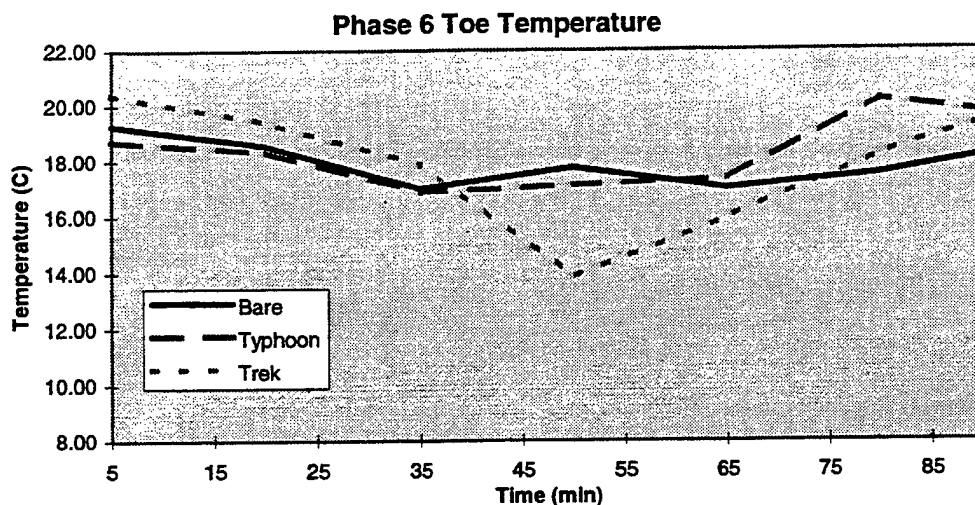
These unavoidable "early removals" from a phase or termination in the entire exposure routine inconsistently affected the analysis of the extremity thermal data. Because the subjects who got coldest were removed from these segments of the analysis, the Trek dry suit artificially appears to have performed better in protecting the extremities, particularly the feet, in the latter phases of the exposure. A trend of the foot temperatures by the 4 major phases of the study are shown in Figures 5-8.



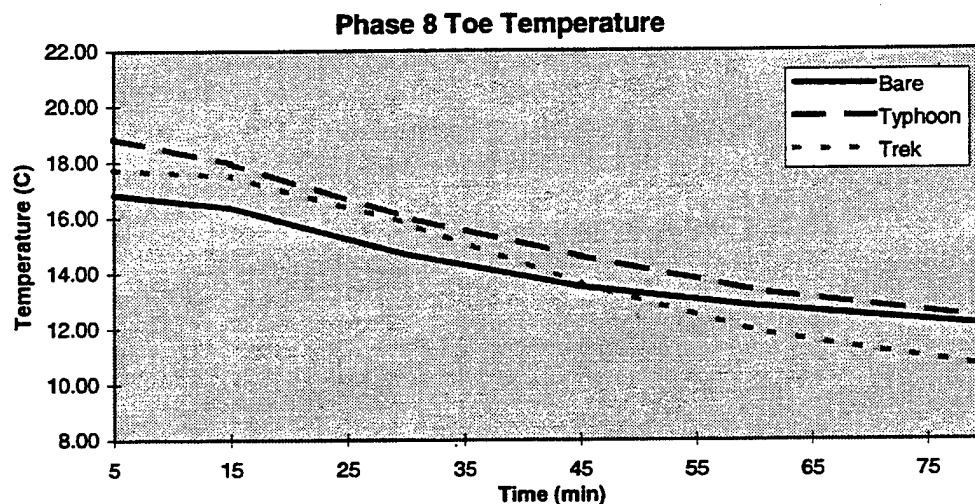
**Figure 5.** Graph of toe temperature vs. time for each dry suit ensemble during Phase 3 (Simulated Boat Transit).



**Figure 6.** Graph of toe temperature vs. time for each dry suit ensemble during Phase 4 (Simulated Turtlebacking).



**Figure 7.** Graph of toe temperature vs. time for each dry suit ensemble during Phase 6 (Simulated Patrolling).

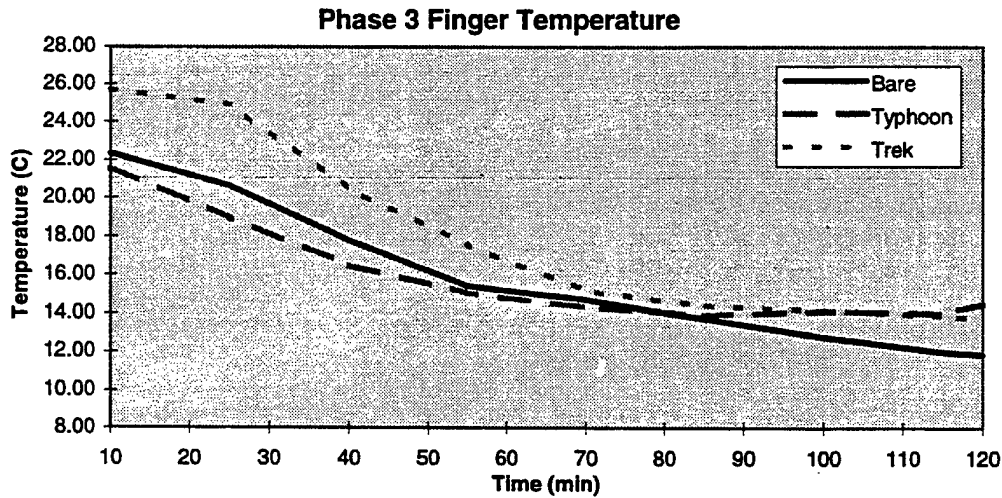


**Figure 8.** Graph of toe temperature vs. time for each dry suit ensemble during Phase 8 (Simulated Boat Transit).

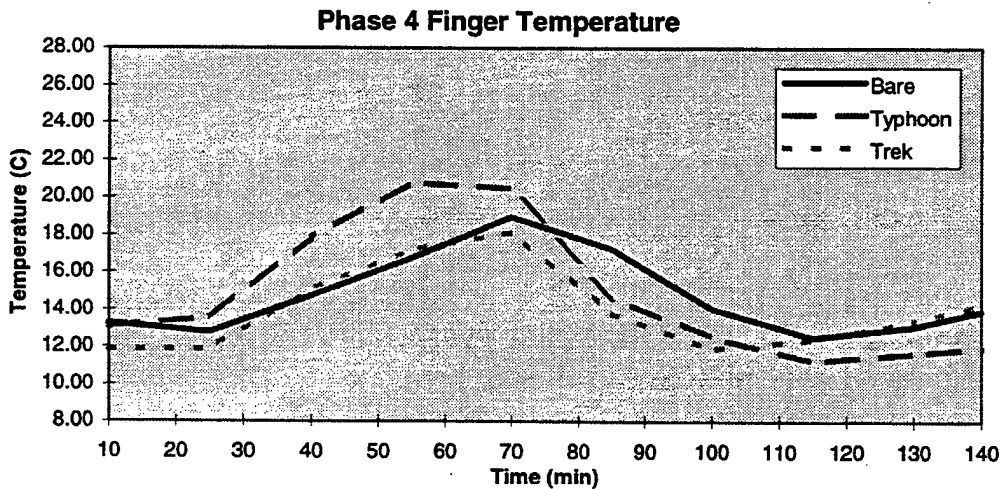
Despite the removal of data from the subjects whose feet reached the limit on foot and toe temperatures (this occurred with 4 of 7 subjects wearing the Trek and 1 of 7 subjects wearing the Typhoon), the Trek suit still consistently provided the least thermal protection for the feet. During Phase 4 (a long turtleback phase), foot temperatures warmed significantly (an increase of  $>5^{\circ}\text{C}$ ) with the Bare and Typhoon

dry suits, but not with the Trek dry suit. This difference was statistically significant ( $p < 0.05$ ).

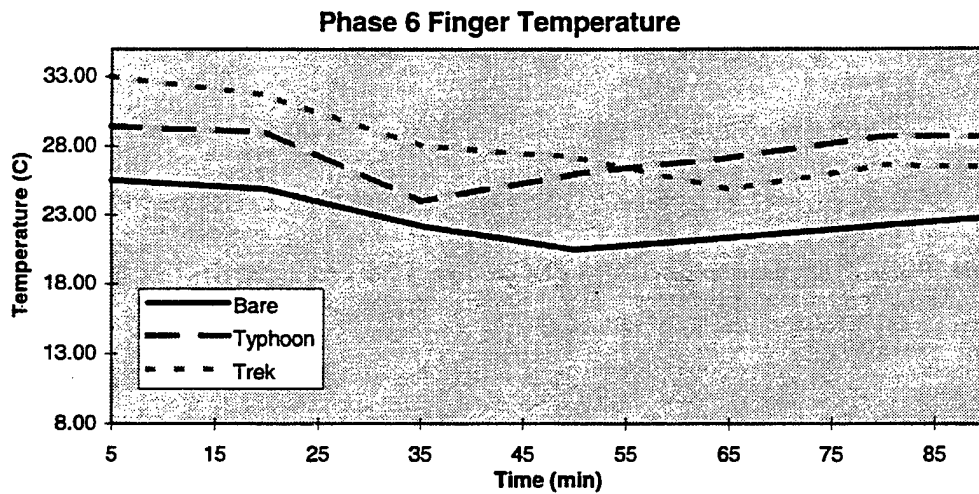
Hand temperatures by the 4 major phases are illustrated in Figures 9 - 12.



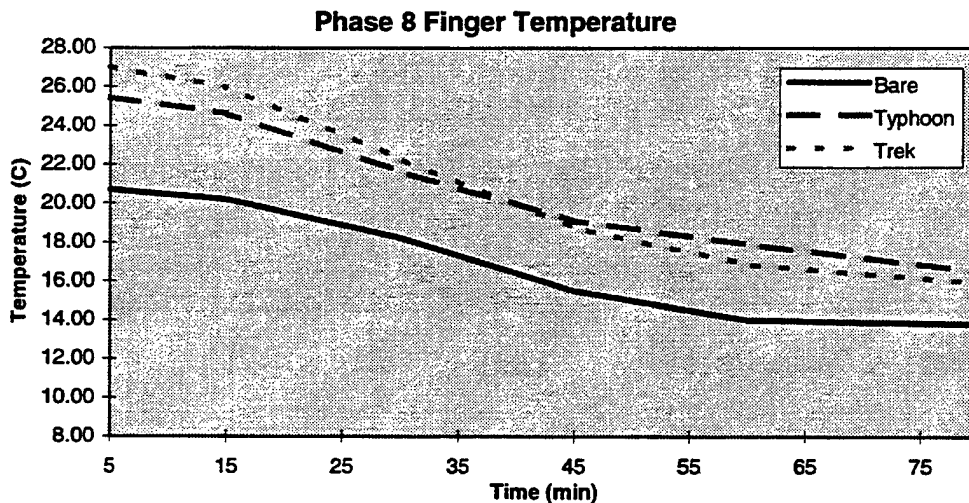
**Figure 9.** Graph of finger temperature vs. time for each dry suit ensemble during Phase 3 (Simulated Boat Transit).



**Figure 10.** Graph of finger temperature vs. time for each dry suit ensemble during Phase 3 (Simulated Turtlebacking).



**Figure 11.** Graph of finger temperature vs. time for each dry suit ensemble during Phase 6 (Simulated Patrolling).



**Figure 12.** Graph of finger temperature vs. time for each dry suit ensemble during Phase 8 (Simulated Boat Transit).

Hand temperatures demonstrated no consistent differences between the suits, but showed a consistent cooling trend throughout the exposure during the simulated boat transit phases. During the phases involving exercise, hand temperatures warmed

significantly (an increase of  $>5^{\circ}\text{C}$ ) or were maintained above  $18^{\circ}\text{C}$  (i.e., in a comfortably warm status).

### ***SOF MRPM Physical And Cognitive Performance Test Results***

The following are the results of the SOF MRPM. The 5 physical tests and the 6 cognitive tests were designed to test SOF mission-related tasks. These tests were administered at the middle and end of the exposure. The physical and cognitive test results are reported below.

#### ***Physical Performance***

Table 2 presents the results of the physical tests as a comparison between baseline, and mid-exposure (Phase 5) values.

**TABLE 2. MEAN RESULTS FROM SOF MRPM MID-EXPOSURE (PHASE 5)  
PHYSICAL PERFORMANCE TESTS**

PHASE 5					
		BASELINE	BARE	TREK	TYPH
Physical:	Manual Dexterity (s)	128	171*	195*	187
	Grip (psi/s) Right hand	169 / 86	155* / 88	145* / 77*	153* / 86
	Grip (psi/s) Left hand	166 / 84	151 / 77	148* / 60*	149* / 3
	Marksmanship				
	%hits / 1 s interval	82	68*	47*	63
	Average time/hit (s)	1.768	1.839	1.977*	1.962*

\* $p < 0.05$  (statistically significant change from baseline)

Compared to baseline, all three ensembles demonstrated significantly increased times during the manual dexterity task (weapon assembly). There was no significant difference between the ensembles.

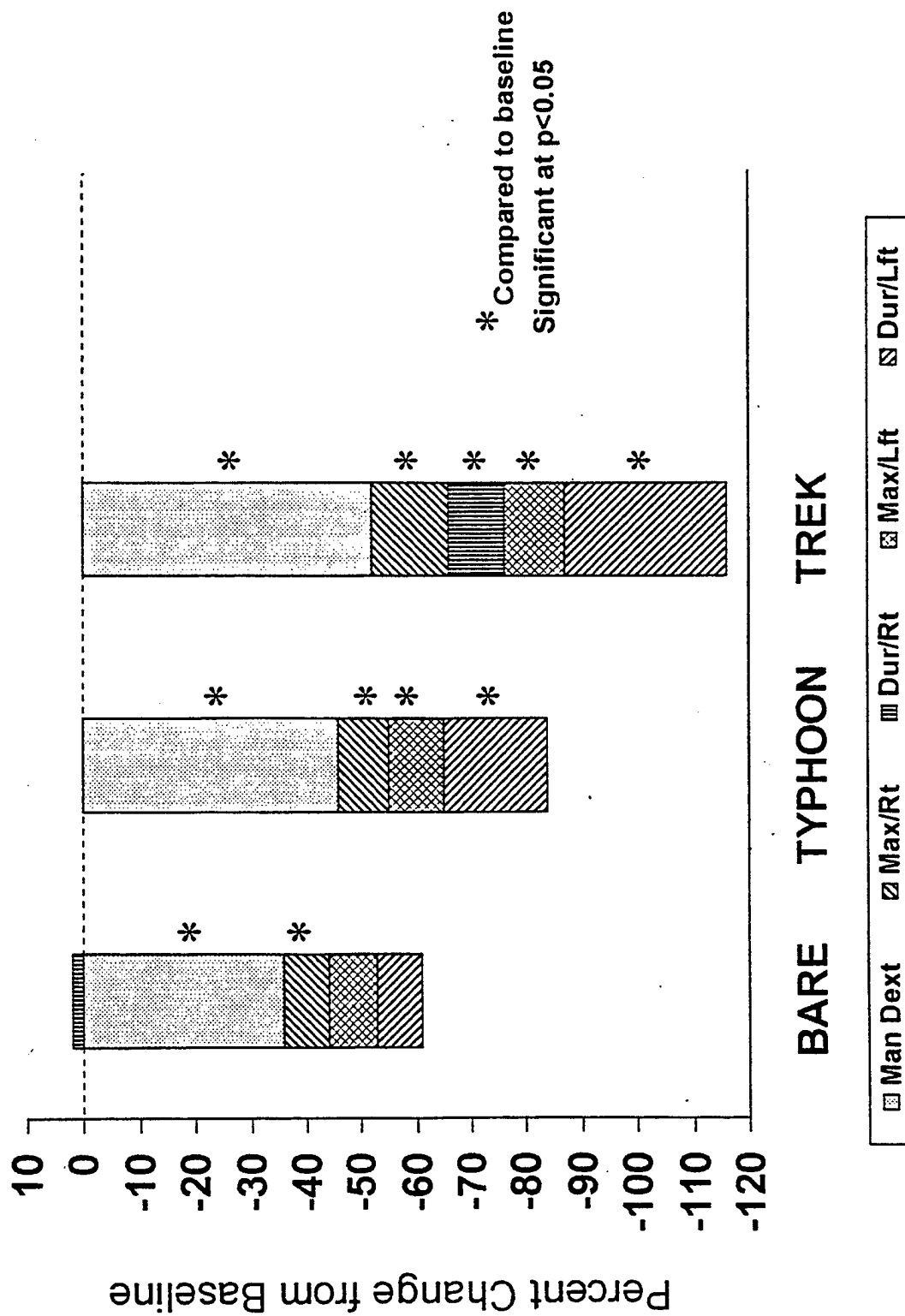
Maximal grip strength with the right hand was also significantly less among all dry suits, with right-hand duration significantly decreased only with the Trek. Maximal grip strength and duration with the left hand was reduced with all ensembles but reached significant levels only with the Typhoon and Trek. Shooting skills in the “%Hits/1s interval” category were significantly degraded with all three ensembles, with the least decrement demonstrated with the Bare ensemble (17% below baseline) and the greatest decrement shown with the Trek (43% below baseline).

The average time it took the shooter to hit the target (Average time/hit), was significantly longer than baseline with both the Typhoon (11%) and Trek (12%).

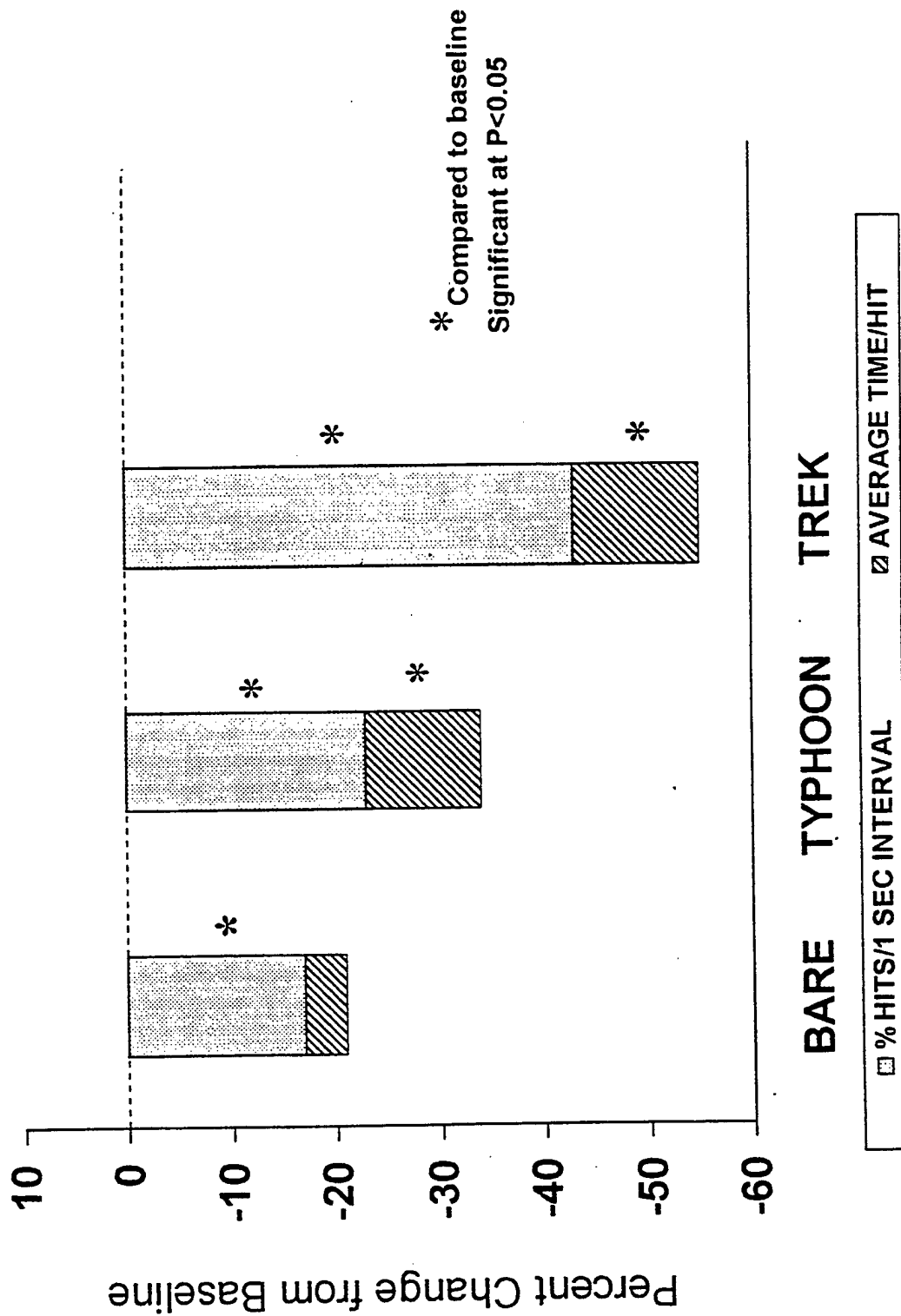
Figures 13 and 14 illustrate the results as a percent change from baseline for each garment ensemble at the mid-exposure point. An increase in the amount of time required to complete a task is represented as a negative % change from baseline performance (e.g., manual dexterity and average time/hit). The relative contribution of each physical task is indicated by the different sub-segments within each bar. While the results cannot be considered physically cumulative, this manner of presentation allows for easy comparison between ensembles.



# PHYSICAL RESULTS MID-EXPOSURE



# SHOOTING RESULTS MID-EXPOSURE



The Bare ensemble had the fewest physical test results that were significantly different from baseline, and the magnitude of the decrements for each test were smaller than for the Typhoon or the Trek. The Typhoon was intermediate with respect to the number of significantly different tests, as well as the magnitude of the decrements.

In all tests, the Trek demonstrated the greatest change from baseline compared to the other garment ensembles. The same pattern was seen in both categories of shooting skills (Figure 14). Decrements in performance were smallest with the Bare ensemble, intermediate with the Typhoon, and greatest with the Trek.

Table 3 presents the results of the physical tests as a comparison between baseline, and end-exposure (Phase 9) values.

**TABLE 3. MEAN RESULTS FROM SOF MRPM END-EXPOSURE (PHASE 9)  
PHYSICAL PERFORMANCE TESTS**

PHASE 9				
	BASLINE	BARE	TREK**	TYPHOON
<b>Physical:</b>				
Manual Dexterity (s)	128	175*	167*	152
Grip (psi/s) Right hand	169 / 86	165 / 90	160* / 84	166 / 90
Grip (psi/s) Left hand	166 / 84	153 / 81	159 / 81	155 / 90
<b>Marksmanship</b>				
%hits / 1 s interval	82	71*	59*	54*
Average time/hit (s)	1.768	1.927*	1.884	1.91
Steps (n) in 60 s	70	70	72	71
Pull-ups (n)	20	22	21	22

\* $p < 0.05$  (statistically significant change from baseline)

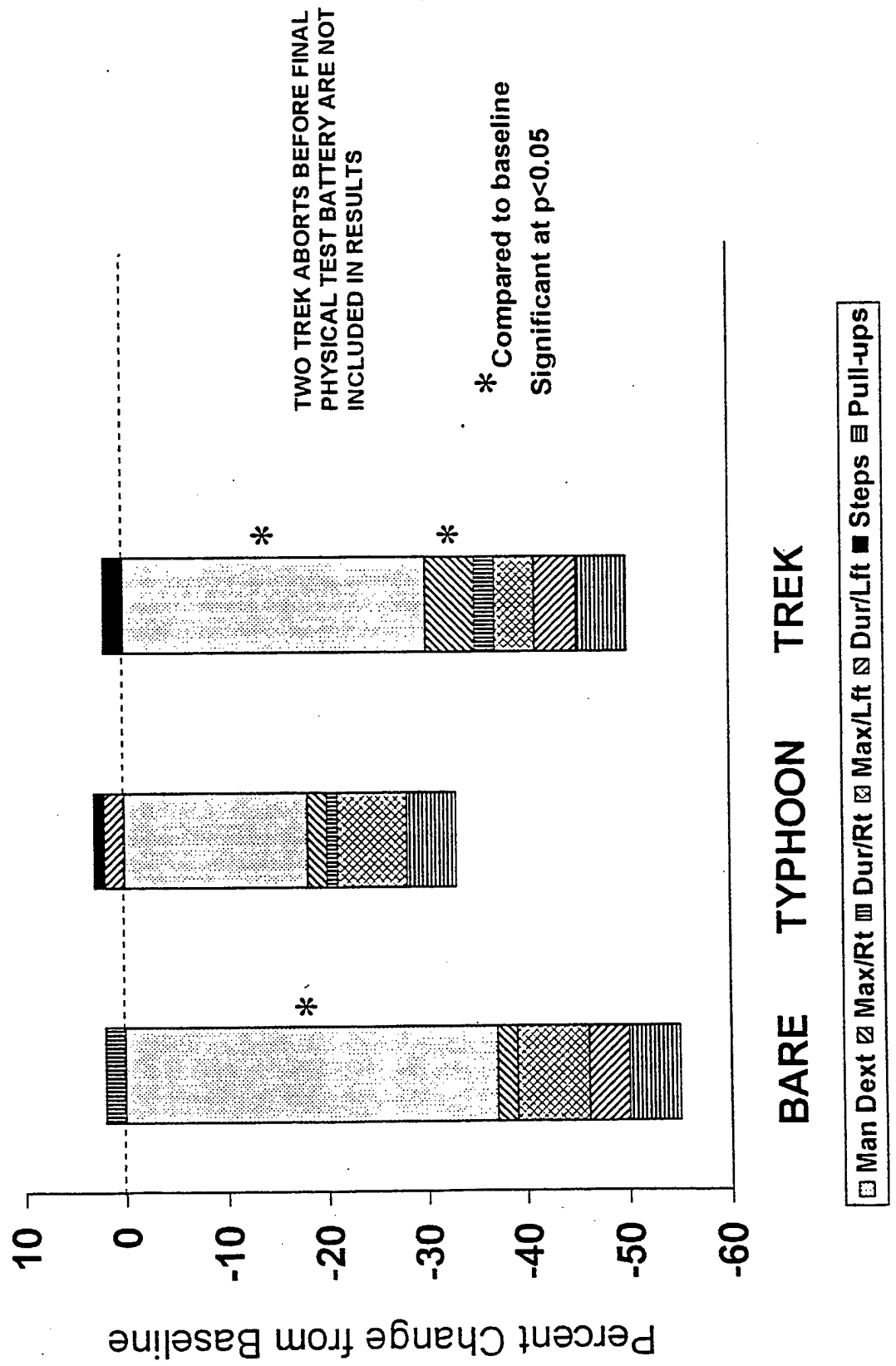
\*\* Two of the subjects wearing the Trek ensemble had to abort well before Phase 9 due to low extremity temperatures and are not included in this analysis.

Manual dexterity times were significantly increased from baseline with both the Trek and Bare ensembles. Maximal grip strength of the right hand was significantly reduced with the Trek. Decrements in performance were demonstrated in all ensembles with respect to the "%Hits/1 s interval" category, while the "Average time/hit" was significantly increased with the Bare and Typhoon.

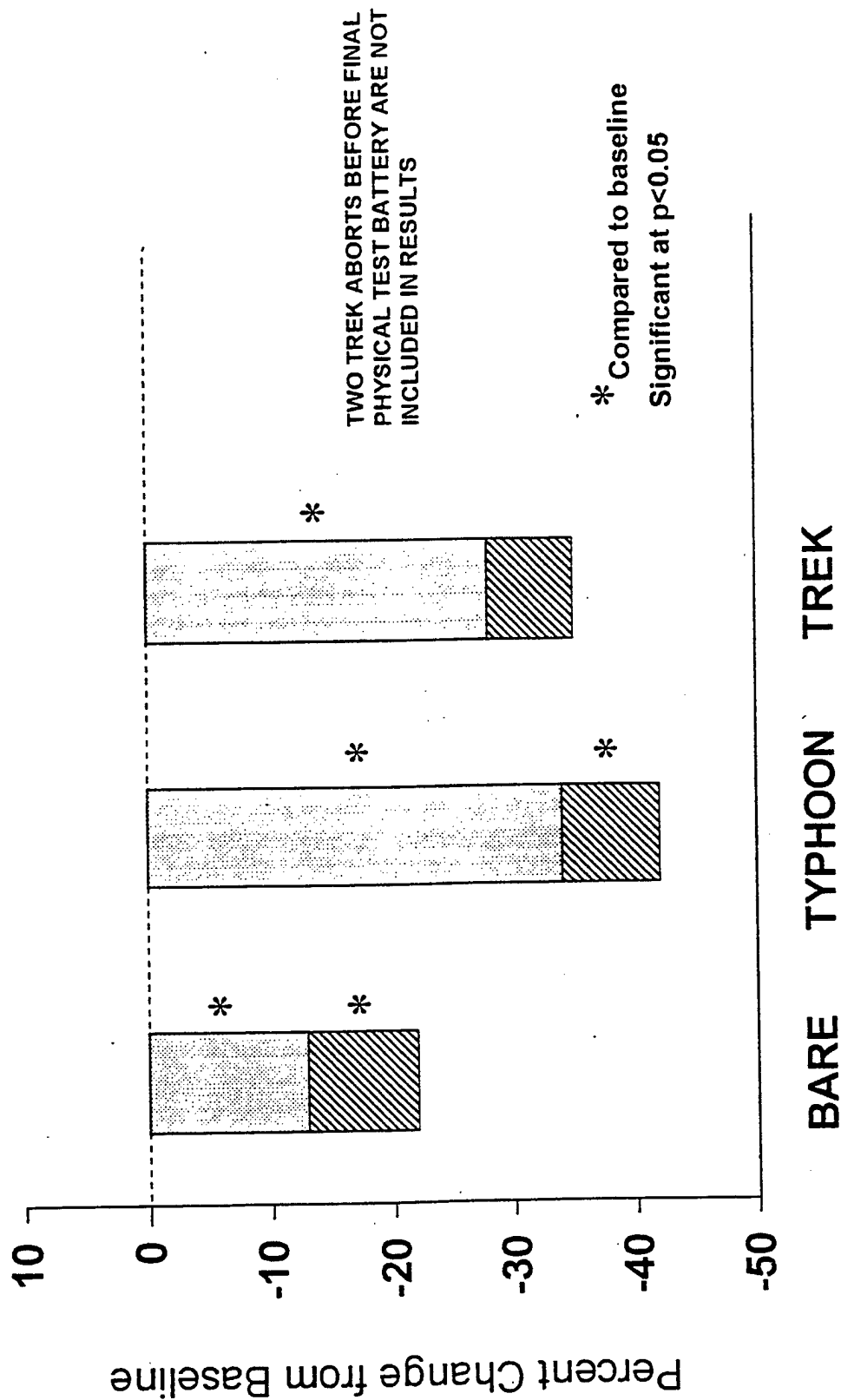
All other physical and shooting results were not significantly different from baseline.

Figures 15 and 16 illustrate the results as a percent change from baseline for each garment ensemble at the end of the exposure.

# PHYSICAL RESULTS END-EXPOSURE



# SHOOTING RESULTS END-EXPOSURE



□ % HITS/1 SEC INTERVAL      ▨ AVERAGE TIME/HIT

Different patterns of performance decrements are seen when compared to mid-exposure patterns. Considering the physical tests, the Typhoon showed a smaller total decrement than either the Bare or Trek, which were similar. When considering shooting skills, the Bare ensemble minimized performance decrements better than either the Typhoon or Trek.

### ***Cognitive Performance***

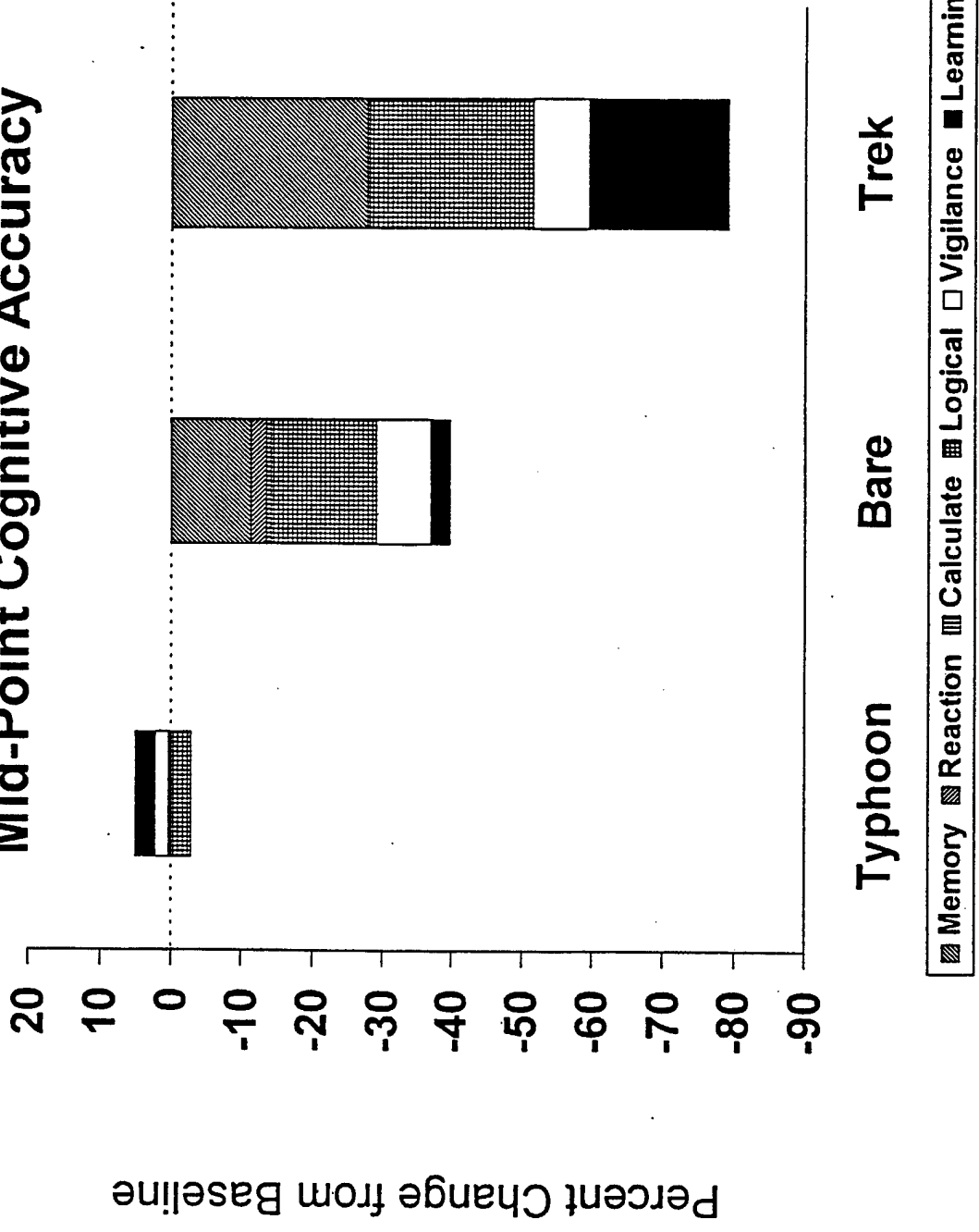
An individual's data for each one of the six cognitive tasks was obtained at the midpoint of a session and immediately following the endpoint of a session. Each individual's data on the performance tasks were converted into a relative score indicating percent change from baseline performance, where baseline performance was the average of the last two baseline sessions. The relative scores for all individuals were then combined and a mean score obtained for each of the three thermal protection garments, so that a single percent change score was obtained for each of the performance measures. For each of the six cognitive measures of Delayed Matching to Sample, Reaction Time, Calculation, Logical Reasoning, Vigilance, and Repeated Acquisition two relative scores were obtained: both an accuracy score (percent correct) and a time score (response time). These were obtained for both the midpoint and end of session measures.

Figures 17 and 18 show the overall change in mean cognitive performance accuracy for each of the three thermal protection garments at the midpoint and session end. The bottom of the Figures indicate the thermal garment evaluated and beneath that is a legend indicating the six cognitive tasks that were used to evaluate the

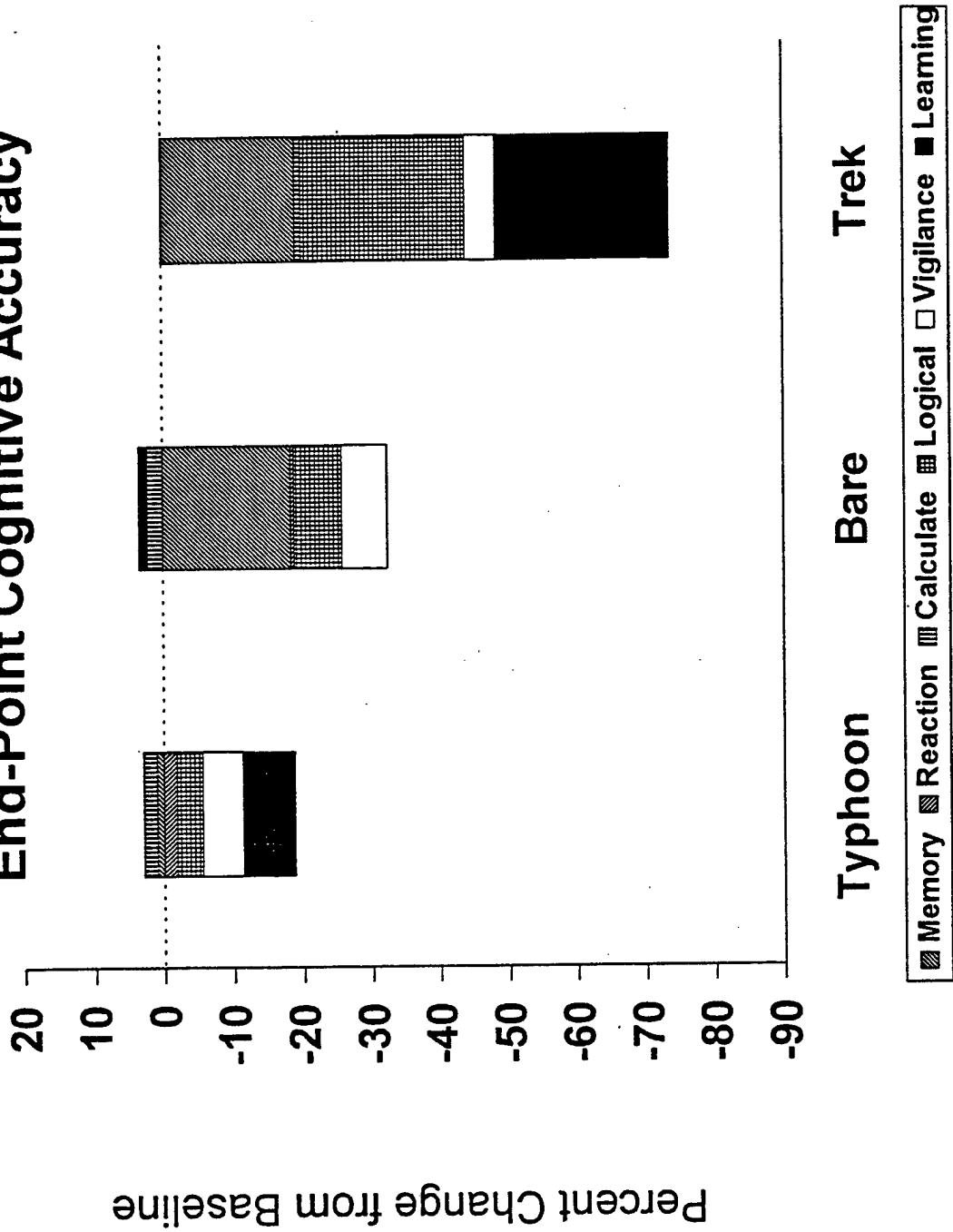
garments, as follows: Memory (Delayed Matching-to-Sample task), Reaction (Complex Reaction Time task) Calculate (Serial Addition/Subtraction task), Logical (Logical Reasoning task), Vigilance (Visual Vigilance task) and Learning (Repeated Acquisition task). The left axis of the figures present the data as the percentage change from baseline. Minus numbers in performance accuracy indicate that the operators made more mistakes on that task than during the baseline condition. The total length in the down direction of a bar indicates the total combined change for the entire mission-related performance measures. The relative contribution of each cognitive task (memory, learning, etc.) to the overall performance decrement is indicated by the different sub-segments within each bar.



# NSWDG Thermal Garment Mid-Point Cognitive Accuracy



# NSWDG Thermal Garment End-Point Cognitive Accuracy



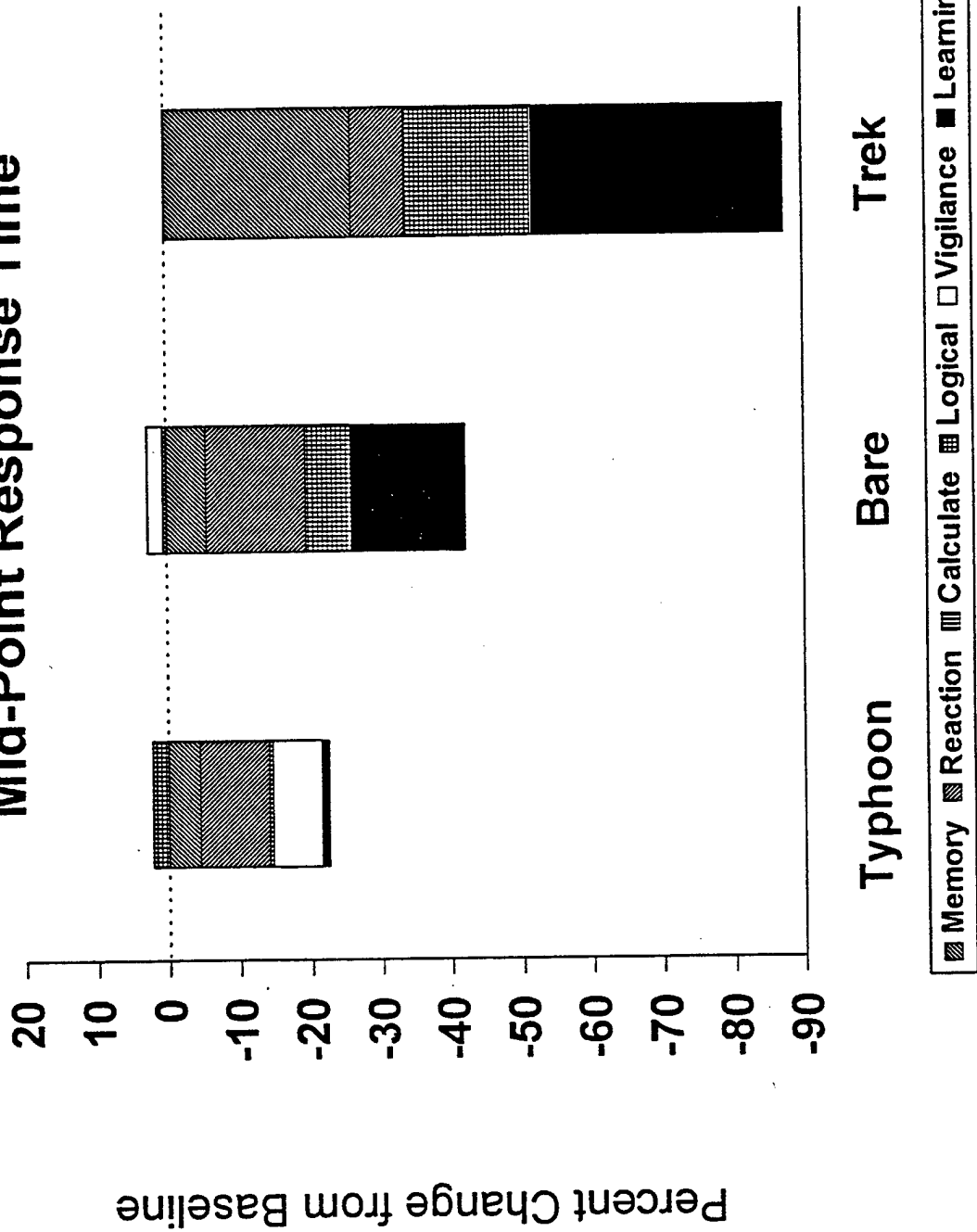
The overall length of the bar for the Trek Suit indicates that an overall decrease in performance accuracy was greatest for this suit (~ - 80 %). The overall decrement in accuracy performance for the Trek suit was mainly a result of decrements in the memory, logical reasoning, and learning sub-segments. The Bare suit showed the second greatest decline in performance accuracy. The Typhoon suit showed no systematic change in performance accuracy from baseline values.

Figures 19 and 20 show the overall change in mean cognitive performance response times for each of the three thermal protection garments. Figures 19 and 20 are arranged in a similar fashion as Figures 17 and 18 except that negative numbers on the left axis in performance response time indicate that the operators took longer to complete a task than during the baseline condition.

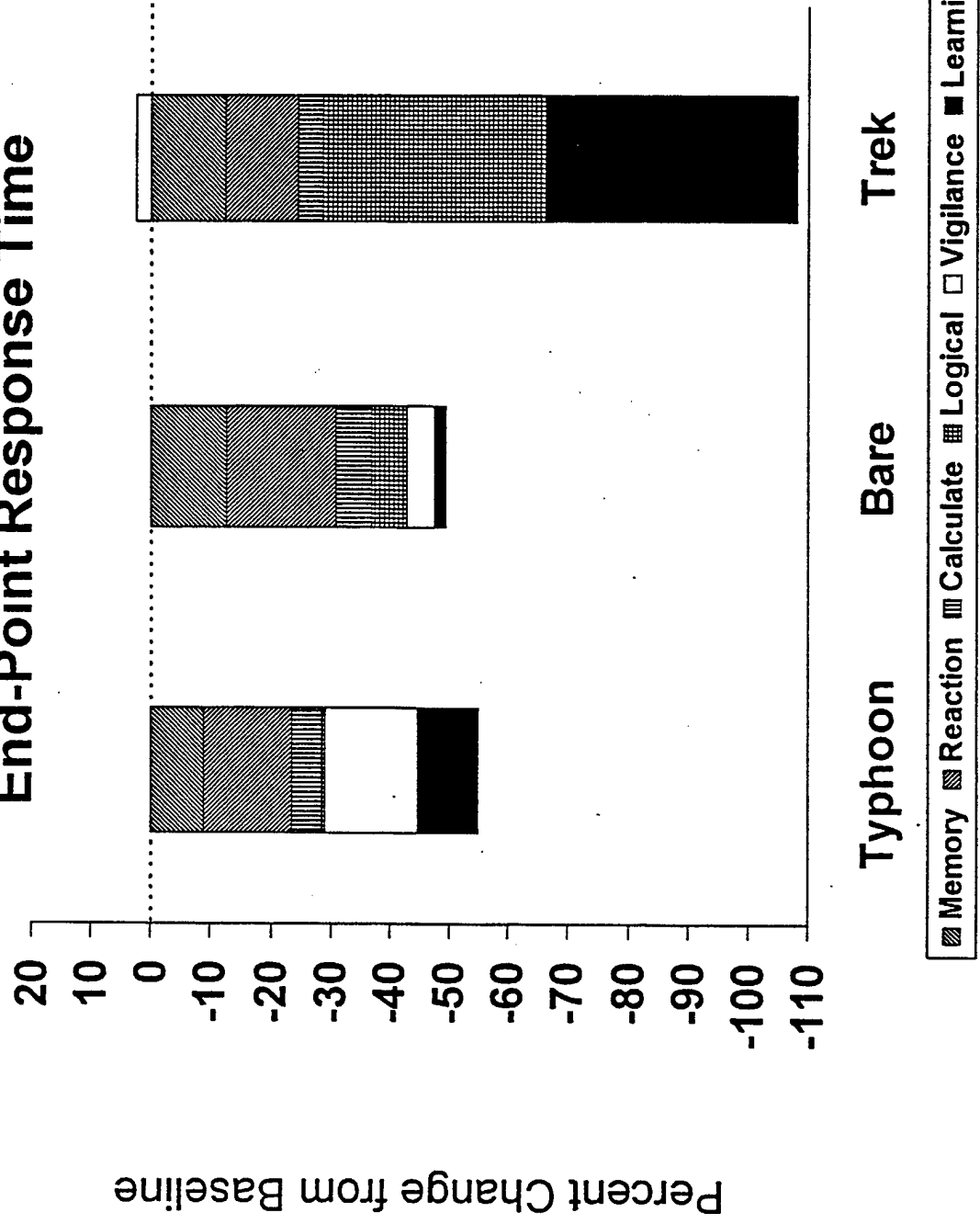
As with performance accuracy, the Trek suit showed the greatest decrement (lengthening) in relative response times. Therefore, not only were less questions answered correctly, but also it took longer to answer them, for the average subject wearing the Trek dry suit compared with the other two ensembles. The overall decrement in cognitive response time for the Trek suit was a result of decrements in memory, logical reasoning, and the learning subsegments. The Bare was second in overall response time decrement at the midpoint.

The Typhoon and the Bare both showed about a 50% decline in overall response time at the session endpoint measure.

# NSWDG Thermal Garment Mid-Point Response Time



# NSWDG Thermal Garment End-Point Response Time



## DISCUSSION

### *Important Issues In NSW Dry Suit Use In An OTB Mission*

#### **1. The Bare dry suit ensemble proved the best option for NSW OTB missions.**

In this study of a simulated OTB operation, the Bare dry suit consistently equaled or out-performed the other two dry suit ensembles in terms of thermal protection, SOF mission-related performance, and subjective SEAL operator evaluations.

The Bare dry suit ensemble consistently exhibited warmer rectal and toe temperatures than the other dry suit ensembles. Additionally, the Bare dry suit ensemble was the only ensemble that had no subjects reach the termination criteria of the study for hand and/or foot temperatures (  $< 8.0^{\circ}\text{C}$  for a 30-minute period, or  $< 6.0^{\circ}\text{C}$  at any time).

Decrements in performance were seen with all of the dry suit ensembles. The mid-exposure results present a clear pattern of degradation relative to which ensemble is worn (Figure 12). Based on the OTB mission scenario, operator performance at the midpoint of the exposure (the actual over-the-beach phase) was judged to be more critical for mission success than performance at the end of the exposure. A partial physical performance battery was conducted at the mid-exposure point, with the greatest decrements being demonstrated in manual dexterity. The overall pattern of degradation indicates that the Bare ensemble produced relatively smaller changes from baseline in all 3 physical tests. There were also fewer tests which demonstrated significant difference with the Bare ensemble compared to the Typhoon and Trek.

Critical importance should be attached to the results of the shooting skills test. In both categories (percentage of rapidly presented targets hit and reaction time), subjects wearing the Bare ensemble demonstrated smaller decrements in performance than both the Typhoon and the Trek ensembles. Figure 14 shows that the decrement in both categories is less than half that seen with the Trek. Operators were better able to react to rapidly presented targets, hitting a higher percentage of those targets more quickly, when wearing the Bare ensemble compared with the Typhoon, and especially the Trek, ensemble.

The Bare dry suit was subjectively ranked the best dry suit for OTB missions by all 7 of the NSWDC SEALs. One of the SEALs commented, "the overall construction of the (Bare) suit was ...better. I believe it would last longer and hold up better... by far the best made."

Some of the suit features that the SEALs liked included the following:

The neoprene neck seal of the Bare suit provided extra warmth to the neck that translated into an improved swimming position in the water (with a chilled neck an individual is more likely to attempt to swim with his neck out, which is less efficient). The neoprene lower leg / calf "gaiter system" of the Bare suit eliminated the need for ankle weights for surface swimming for most of the SEALs and decreased the amount of "crushing" of the dry suit around the lower legs when vertical in the water. The integral neoprene boots of the Bare suit were warmer and more comfortable than conventional dry suit boots.

## **2. The SEAL operators unanimously ranked the suits as follows:**

<b>Outergarment:</b>	<b>#1 - Bare</b>
	<b>#2 - Typhoon</b>
	<b>#3 - Trek</b>
<b>Undergarment:</b>	<b>#1 - Andy's Undies</b>

Specific recommendations for dry suit design and use in NSW operations are listed later in this report.

## **3. Hand and foot thermal protection must be improved**

All three of the dry suit ensembles tested in this study did an adequate job of protecting core body temperatures for the full 8 hour exposure. However hand and foot temperatures were not maintained in an area preferable for NSW operations. One of the SEALs commented "...my body is good to go but my feet and hands are really (very) cold."

These cold extremities may affect operational performance. As another SEAL noted, "Dexterity is horrible after coming out of that cold water, so if you were being tasked with doing some meticulous job . . . you may have some problems." This study supports that comment.

Through numerous previous thermal studies the following can be said about hand/finger temperatures and sensation/performance (13).



<u>Hand/Finger Temp</u>	<u>Sensation / Performance</u>
18 °C	Hands feel mildly cold.
15 °C	Hands feel uncomfortably/painfully cold.
10 °C	Skin over hand is numb, but pain persists because its origin is from constricted blood vessels.
8 °C	If skin temps persist for a long period of time at this level, there is a risk of NFCI (permanent tissue damage).
0 °C	By definition, frostbite (permanent cellular death) occurs when skin cells freeze.

In this study it can be seen that with all of the ensembles, frequently low hand temperatures caused hands to feel painfully cold/numb. Low hand temperatures correlated well with the decrements seen in the test of manual dexterity (weapon disassembly/assembly task).

**Table 4. The Average Time To Field Strip A Weapon And Reassemble It During Phases 5 And 9.**

PHASE 5				
	BASELINE	BARE	TREK	TYPHOON
Physical: Weapon assembly (sec)	128	171*	195*	187
PHASE 9				
	BASELINE	BARE	TREK**	TYPHOON
Physical: Weapon assembly (sec)	128	175*	167*	152

\*p < 0.05 (statistically significant change from baseline)

\*\* Two of the subjects had to abort before phase 5 due to low extremity temperatures and are not included in the phase 9 analysis.

Therefore, with all of the ensembles tested, hands got cold and this significantly degraded manual dexterity. Hand thermal protection appears to be the most common

mission-limiting factor in cold weather NSW OTB missions. To improve upon this, the following suggestions are offered.

To improve the thermal protection of the hands we suggest looking at the boat transit phase of NSW operations. This phase is typically the coldest (as seen in this study) and yet probably the most easily improved upon phase. During this phase the possibility of active heating is most easily accomplished (little individual movement necessary and a large platform for holding a power source/ batteries). Also, since fine use of the hands is not usually necessary, bulky passive garments that are easily shed are also an option worth further investigation for the boat transit phase.

In summary, hand and foot thermal protection continues to be the greatest challenge in cold-weather operations and must be an area of ongoing research and development.

#### **4. Development of a combined NBC, fire-retardant, and thermal protective dry suit**

One of the subjects noted in a post-dive debrief that the dry suit of the future should do more than just provide thermal protection, it should also be safe in a Nuclear, Biological and Chemical (NBC) and fire-threat environment. Although this concept was not tested in this study, this comment is important and is simply offered for future planners.

#### **5. There is great individual variability in response to thermal stress**

While two people may have the same thermal protective ensemble, and perform the same workload, their core and extremity temperature changes and ability to simply

endure a cold exposure may be very different. This was certainly seen in this study and may be appreciated by closely reviewing Appendix A (the Individual Exposure Data).

Operational commanders must take these differences into account when selecting their mission team. Also, each member of the team must take this into account when selecting their individual thermal protection.

#### **6. No dry suit will satisfy all NSW requirements**

Because of the great variety of NSW missions, no garment will be superior in every application (at this time). For a mostly diving / swimming operation one suit may be superior, while for an OTB operation another suit may be better. As one SEAL stated, "I wore the Nokia (dry suit) at SDV team 1 and never had a problem with it (was good in an SDV application), but it is thicker and heavier than this dry suit and would not work for all SPECWAR applications."

#### **7. Operational testing of dry suit garments**

Each command and each mission scenario may require different operational testing. The areas of further operational testing are summarized as follows:

- Donning / doffing in field
- Areas to reinforce and put pockets
- Patrolling requirements
- Exposure to pyrotechnic diversionary devices, hot brass, etc.
- Compatibility with body armor
- Suit inflation/deflation valve requirements (for diving)
- CQB Issues (overheating, sweating, cool-down)

## **8. Areas of suit reinforcement for NSW use**

As learned in this study, the crotch / inner thighs of the dry suit must be reinforced for any operation involving a caving ladder climb (one subject ripped a small hole in the crotch of a new Trek dry suit after performing a proper caving ladder climb and completely compromised his thermal protection). Other areas of suit reinforcement suggested by the subjects included knees, lower legs, elbows, seat, forearms, and gloves.

## **9. Custom fit is essential**

For Navy SEALs, proper fit translates into mobility in the water and on land. The properly fitted garment does not restrict swimming, climbing or patrolling and yet is not too baggy to make burping a suit or wearing operational gear difficult.

## **10. Physical and cognitive performance were significantly degraded by cold exposure**

Clear decrements in both physical and cognitive performance were seen at both the middle and end of the experimental exposure. While the pattern of degradation in cognitive performance was consistent at the mid-point and end of the exposure (the greatest decrements seen with the Trek suit followed by the Bare and the Typhoon), the physical performance data showed a less consistent pattern. In other words, the pattern of physical performance degradation related to ensemble is not as clear with the end-exposure results as with the mid-exposure results. Two issues may have affected the change in the pattern of the physical performance results:

1) Two exposures were aborted with the Trek ensemble for safety reasons because of low toe and finger temperatures. For analysis purposes this required the removal of those subjects' data from the results. In an operational setting these subjects would have continued their mission/exposure regardless of finger and toe temperatures and then performed mission-essential tasks. Early removal from the study exposures most certainly eliminated data that would have reflected their significantly degraded performance, and by its absence shifted the Trek data in a more positive direction.

2) Multiple transitions from water to chamber and vice versa took place after the mid-exposure tests. The combined level of exercise (in the chamber and the water) during the phases after the mid-exposure tests was greater than during the earlier phases. These additional transitions and exercise phases present opportunities to cool and rewarm differently than during the earlier phases.

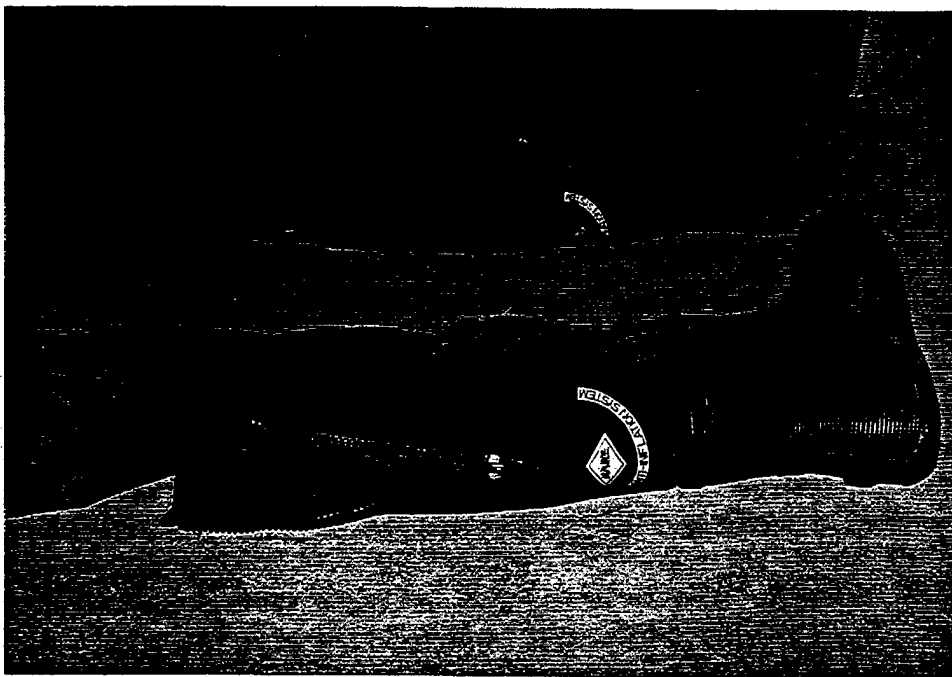
The results of the end-exposure shooting skills tests were consistent with the mid-exposure results - subjects wearing the Bare ensemble demonstrated smaller decrements in performance compared to the Typhoon or Trek. Again, the absence of data from the two early terminations of the Trek ensemble meant that the decrements in performance were less severe than if those two subjects had completed the exposure regimen and the end-exposure performance tests.

### ***SEAL / Individual Subject's Suit Evaluations***

At the completion of each exposure, each subject was interviewed. They were asked to evaluate each suit's strengths and weaknesses, and make recommendations

for improvements based on operational considerations. The collective recommendations for dry suit use and specific improvements for dry suit design in NSW operations are listed below:

- **The neoprene neck seal of the Bare suit provided extra warmth to the neck that enabled an improved swimming position in the water** (with a chilled neck an individual is more likely to attempt to swim with his neck out which is less efficient). A neoprene neck seal must be custom fit taking into account the fact that the neck seal will stretch with use.
- **The neoprene lower leg / calf "gaiter system" of the Bare suit eliminated the need for ankle weights for surface swimming for most of the subjects** and it also decreased the amount of "crushing" of the dry suit around the lower legs when vertical in the water.



**Photo 24.** Neoprene "gaiter" system and integral neoprene boots of BARE dry suit

- **The integral neoprene boots of the Bare and Typhoon suits were warmer and more comfortable than conventional dry suit boots.** While the undergarment thermal protection varied (the Bare was worn with only an insulating sock and the

Typhoon had a thinsulate bootie), both of the suits with the integral neoprene boots were rated better than the Thinsulate undergarment bootie and thin rubber outer boots of the Trek ensemble. This difference was even greater in the water when the neoprene boots resisted the crushing effect of the water pressure. **A suggestion for the future was to build the neoprene boots with the fit of a sneaker and with a puncture-proof insulated sole to enhance patrolling in the dry suit.**

- **Standard wet suit fins will not fit when wearing a dry suit.** All the subjects recognized the need for a fin designed to fit over the larger bootie of a dry suit.
- **Recommend a front-entry zipper that ends on the opposite shoulder from the shooting shoulder.** A front-entry zipper was preferred in the event of the need to don or doff the suit alone. However, the zipper interfered with marksmanship if it ended on the shooting shoulder.
- **Both the entry and relief zipper should be covered with a flap to protect the main zipper from sand.** As one subject noted, "...if you get any kind of sand (in the zipper) when you are going to zip the zipper then it will rip (and ruin the entire dry suit)." The subjects were split on whether velcro (which is noisy, but will not freeze) or a plastic zipper (which is not noisy, but will freeze) would be the best protective cover.
- **Recommend large toggle handles with a velcro stow pocket for the zipper handles.** The large handles were necessary to open the zippers with a gloved hand. The stow pocket was necessary to insure the suit was not inadvertently opened. Additionally, the subjects recommended large handles for the zippers of the undergarments so they also could be opened with a gloved hand.
- **Keep suit penetrations to a minimum.** In this study of a simulated boat transit and OTB mission that required no diving, suit penetrators were not deemed necessary. This minimized the possible points of suit failure. The trade-off was greater difficulty burping / inflating the suit. As one subject put it, "(Range of motion in the pool was) o.k. when burped properly, (but) some experience is required to know how tight to get the suit. Buoyancy will make OTB's tough in big surf. (We should) try some suits with valves for deflation." After field testing, a suit purge valve and/or oral inflator, (in order to best control suit buoyancy) may be recognized as a "necessity".
- **External pockets in a dry suit are very useful** for stowing hood, gloves, flares, etc., but need to be customized after field testing.
- **Recommend Andy's underwear for the undergarment,** due to its' comfort and warmth, but recommend it be better sewn down to prevent the bunching of material in the extremities.

- **Dry suit gloves need further development.** Of the gloves tested, there were a number of different opinions. For example, while most of the subjects believed the glove ring system of the Trek dry suit was an operational liability, some thought it may provide additional hand warmth and comfort for a boat coxswain (whose role does not include swimming, patrolling, donning/doffing the suit in the field, etc.). The subjects agreed that a 3-finger mitten or a large "over-mitten" for the boat transit phase would be better than 5-finger gloves. In general, however, hand and foot thermal protection continues to be the greatest challenge in cold-weather operations and must be an area of ongoing research and development.
- **The "Gorilla" balaclava,** with the addition of a Gore Wind-Stopper™ / windproof outer shell, was recommended for the boat transit phase.

## SUMMARY

Appendix A summarizes all of the individual cold exposures in this study. The information includes identifying the individual subject, the garment worn, their changes in rectal, finger, and toe temperatures over the exposure routine, their "ins and outs" (what they ate/drank and how much they urinated) and their scores on the performance tests.

Enclosure A is a VHS videotape summary of this study. It is approximately 15 minutes in duration and gives a visual summary of the methods and results of the study.



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**APPENDIX A**  
**INDIVIDUAL EXPOSURE DATA**

**TABLE 5. PHYSICAL CHARACTERISTICS OF SUBJECTS**

<i>Subject</i>	<i>Age (years)</i>	<i>Height (in.)</i>	<i>Weight (lb.)</i>
A	34	67.5	168
B	27	66.5	166
C	35	71	186
D	30	71	194
E	33	75	210
F	30	72	202
G	30	70	227

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			82	36.4	30.5	26.7				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	94	36.7	18.9	24.0	525	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	72	36.9	14.8	21.8				
	35 min	Exit Pool	73	36.9	13.8	21.1				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	62	36.9	16.5	18.9	325	0	1	None
	25 min		63	37.0	18.3	15.5				
	40 min		72	36.9	17.3	13.4				
	55 min		66	36.8	14.8	11.3				
	1 hr 10 min		72	36.8	13.9	10.0				
	1 hr 25 min		72	36.7	12.9	9.4				
	1 hr 40 min		72	36.7	12.0	9.0				
	1 hr 55 min		60	36.5	11.7	8.7				
	2 hr	Exit Chamber	72	36.5	11.9	8.4				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	84	36.5	12.5	10.1	550	500	0	Cheese&Crackers Tootsie Roll Pound Cake
	25 min		84	36.8	9.4	10.4				
	40 min		84	37.0	10.0	10.6				
	55 min		84	37.2	9.8	11.1				
	1 hr 10 min	Stationary (40 min)	72	37.1	20.1	15.1				
	1 hr 25 min		60	36.9	15.3	13.3				
	1 hr 40 min	Turtleback (40 min)	60	36.8	12.9	12.4				
	1 hr 55 min		84	36.9	11.9	11.6				
	2 hr 10 min		72	37.1	11.6	10.9				
	2 hr 20 min	Exit Pool	84	37.3	10.8	10.7				
	PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 205							
		Grip Strength (psi/sec) = Right 142/64; Left 146/59								
		Shooting (hits/50 targets) = 37								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	76	37.2	25.2	12.4	0	300	0	None
	20 min		60	37.2	23.4	10.4				
	35 min	Skiing (20 min)	84	37.2	20.9	9.1				
	50 min	Seated (10 min)	60	37.2	16.2	16.2				
	1 hr 5 min	Skiing (20 min)	84	37.3	13.5	10.1				
	1 hr 20 min	Seated (10 min)	72	37.3	14.5	11.6				
	1 hr 30 min	Exit Chamber	72	37.4	14.9	11.6				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	99	37.2	13.6	11.7	220	200	1	None
	15 min	Exit Pool	87	37.3	10.8	11.6				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	71	37.3	16.4	12.3	0	0	0	None
	15 min		72	37.3	15.7	11.4				
	30 min		68	37.3	15.7	10.0				
	45 min		61	37.2	13.9	9.5				
	1 hr	Cognitive SOF PAB (30 min)	61	37.1	11.8	9.8				
1 hr 20 min	Exit Chamber	89	36.9	10.9	10.9					
PHASE 9 Post Exposure		Manual Dexterity (sec) = 163								
		Grip Strength (psi/sec) = Right 152/73; Left 156/69								
		Shooting (hits/50 targets) = 43								
		Step Test (# in 60 sec) = 73								
		Pull-Ups (max #) = 26								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result premature termination of the exposure routine.

55 minutes into Phase 4, subject reported diminished feeling and numb sensation in his right hand due to restricted blood flow result of constriction by the wrist seal. Drysuit wrist seal was trimmed. Correlate finger temperature with reduced blood flow.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			91	37.1	NR	24.5				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	103	37.1	NR	21.7	500	0	0	None
	30 min	Stationary (10 min)	127	37.3	23.8	19.0				
	35 min	Climb Caving Ladder Exit Pool	75	37.3	20.3	18.4				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	70	37.3	16.2	15.7	550	50	1	None
	25 min		73	37.3	13.6	14.0				
	40 min		72	37.2	13.9	11.7				
	55 min		65	37.0	12.9	10.7				
	1 hr 10 min		65	36.8	12.1	9.0				
	1 hr 25 min		55	36.8	13.1	8.9				
	1 hr 40 min		61	36.6	12.1	8.8				
	1 hr 55 min		73	36.7	10.3	8.1				
	2 hr	Exit Chamber	78	36.7	9.9	7.9				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	103	36.8	10.1	9.0	1,525	650	1	Cheese&Crackers M&Ms
	25 min		101	37.3	9.8	15.5				
	40 min		100	37.5	16.5	22.6				
	55 min		98	37.7	24.7	26.0				
	1 hr 10 min	Stationary (40 min)	83	36.6	28.8	26.9				
	1 hr 25 min		73	37.3	18.8	22.7				
	1 hr 40 min	Turtleback (40 min)	70	37.1	12.9	18.3				
	1 hr 55 min		110	37.1	10.1	15.8				
	2 hr 10 min		97	37.4	12.0	14.2				
	2 hr 20 min	Exit Pool	112	37.6	10.5	13.1				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 180 Grip Strength (psi/sec) = Right 150/64; Left 160/50 Shooting (hits/50 targets) = 42								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	88	37.5	33.8	13.1	0	0	0	None
	20 min		85	37.5	34.4	12.2				
	35 min	Skating (20 min)	94	37.3	29.6	10.1				
	50 min	Seated (10 min)	97	37.5	29.4	8.9				
	1 hr 5 min	Skating (20 min)	91	37.4	25.9	7.2				
	1 hr 20 min	Seated (10 min)	99	37.6	22.4	7.8*				
	1 hr 30 min	Exit Chamber	NR	NR	NR	NR				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	93	37.7	24.5	8.9	275	0	1	None
	15 min	Exit Pool	92	37.8	25.8	9.1				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	88	37.9	33.8	10.0	0	0	0	None
	15 min		82	37.7	30.5	9.3				
	30 min		87	37.7	24.6	7.3				
	45 min		82	37.5	19.5	7.6**				
	1 hr	Cognitive SOF PAB (30 min)								
	1 hr 20 min	Exit Chamber								
PHASE 9 Post Exposure		Manual Dexterity (sec) = 151 Grip Strength (psi/sec) = Right 164/58; Left 145/66 Shooting (hits/50 targets) = 36 Step Test (# in 60 sec) = 71 Pull-Ups (max #) = 26								

\*Subject removed during Phase 6 ten minutes early due to low toe temperature.

\*\*Phase 8 exposure was terminated 35 minutes early due to low toe temperature.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			79	37.1	31.2	27.2				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	99	36.4	NR	24.0	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	74	36.4	13.1	20.7				
	35 min	Exit Pool	69	36.7	12.0	19.9				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	67	36.4	18.6	18.2	400	0	0	None
	25 min		64	36.4	17.0	15.2				
	40 min		61	36.4	16.2	13.2				
	55 min		80	36.4	15.5	9.5				
	1 hr 10 min		72	36.4	11.5	7.1*				
	1 hr 25 min									
	1 hr 40 min									
	1 hr 55 min									
	2 hr	Exit Chamber								
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	79	36.4	9.0	8.8	0	0	0	None
	25 min		77	36.4	7.7**	10.0				
	40 min									
	55 min									
	1 hr 10 min	Stationary (40 min)								
	1 hr 25 min									
	1 hr 40 min	Turtleback (40 min)								
	1 hr 55 min									
	2 hr 10 min									
	2 hr 20 min	Exit Pool								
PHASE 5 Exposure Cessation		Manual Dexterity (sec) =								
		Grip Strength (psi/sec) = Right ; Left								
		Shooting (hits/50 targets) =								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)								
	20 min									
	35 min	Skiing (20 min)								
	50 min	Seated (10 min)								
	1 hr 5 min	Skiing (20 min)								
	1 hr 20 min	Seated (10 min)								
	1 hr 30 min	Exit Chamber								
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)								
	15 min	Exit Pool								
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)								
	15 min									
	30 min									
	45 min									
	1 hr	Cognitive SOF PAB (30 min)								
	1 hr 20 min	Exit Chamber								
PHASE 9 Post Exposure		Manual Dexterity (sec) = 254								
		Grip Strength (psi/sec) = Right 135/78; Left 131/66								
		Shooting (hits/50 targets) = 36								
		Step Test (# in 60 sec) = 75								
		Pull-Ups (max #) = 26								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result premature termination of the exposure routine.

\* Subject removed during Phase 3 forty-five minutes early due to low toe temperature.

\*\*The entire exposure was terminated at 25 minutes into phase 4 due to low finger temperature.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				U/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			76	37.3	27.9	25.8				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	119	37.5	18.8	24.3	100	0	1	None
	30 min	Stationary (10 min) Climb Caving Ladder	67	37.8	17.1	20.9				
	35 min	Exit Pool	72	37.6	19.0	19.9				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	62	37.5	18.2	20.3	100	0	2	None
	25 min		71	37.4	16.5	17.6				
	40 min		75	37.2	13.3	8.6*				
	55 min		86	37.0	10.9	13.8				
	1 hr 10 min		76	36.9	9.7	12.0				
	1 hr 25 min		85	36.8	9.5	10.9				
	1 hr 40 min		74	36.8	8.2	10.7				
	1 hr 55 min		72	36.8	NR	11.2				
	2 hr	Exit Chamber	NR	NR	NR	NR				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	105	36.8	13.2	11.5	0	800	0	Honey Roasted Peanuts
	25 min		107	37.1	11.0	11.3				
	40 min		82	37.4	17.1	10.8				
	55 min		88	37.4	21.1	10.7				
	1 hr 10 min	Stationary (40 min)	68	36.9	16.3	10.3				
	1 hr 25 min		72	36.8	14.6	10.1				
	1 hr 40 min	Turtleback (40 min)	94	36.7	16.5	10.4				
	1 hr 55 min		98	36.9	10.7	10.3				
	2 hr 10 min		90	37.0	11.0	10.1				
	2 hr 20 min	Exit Pool	92	37.1	10.6	9.9				
	PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 140 Grip Strength (psi/sec) = Right 146/49; Left 111/67 Shooting (hits/50 targets) = 28							
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	63	36.9	26.6	11.6	0	0	1	None
	20 min		83	37.0	25.8	10.8				
	35 min	Skiing (20 min)	113	36.9	25.0	9.6				
	50 min	Seated (10 min)	107	37.1	25.2	10.9				
	1 hr 5 min	Skiing (20 min)	103	37.2	24.4	11.4				
	1 hr 20 min	Seated (10 min)	88	37.3	24.2	14.0				
	1 hr 30 min	Exit Chamber	77	37.4	23.9	16.3				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	97	37.3	17.5	17.2	350	0	1	M&Ms
	15 min	Exit Pool	111	37.4	13.1	16.5				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	69	37.5	15.9	17.4	0	0	1	None
	15 min		75	37.4	17.8	17.6				
	30 min		65	37.4	16.2	17.3				
	45 min		60	37.3	15.6	15.6				
	1 hr	Cognitive SOF PAB (30 min)	60	37.1	12.7	13.4				
	1 hr 20 min	Exit Chamber	56	36.9	13.9	11.3				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 151 Grip Strength (psi/sec) = Right 161/71; Left 144/78 Shooting (hits/50 targets) = 39 Step Test (# in 60 sec) = 71 Pull-Ups (max #) = 21								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

\* Erratic toe sensor reading at the 40 minute mark of Phase 3 was determined to be the result of a faulty cable lead. Cable was replaced in the environmental chamber.



PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			97	37.0	26.0	24.0				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	124	37.6	21.0	21.0	0	100	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	103	37.5	14.5	19.5				
	35 min	Exit Pool	90	37.6	16.0	19.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	74	37.5	30.0	17.9	0	0	2	None
	25 min		55	37.2	24.2	15.1				
	40 min		75	37.0	18.2	13.0				
	55 min		67	37.0	14.9	10.9				
	1 hr 10 min		67	36.7	14.8	9.2				
	1 hr 25 min		68	36.6	12.0	8.0				
	1 hr 40 min		68	36.6	12.2	7.3				
	1 hr 55 min		70	36.5	12.5	7.0				
	2 hr	Exit Chamber	NR	NR	NR	NR				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	108	36.7	11.7	9.0	1,000	800	1	BBQ Pork&Rice M&Ms
	25 min		114	37.0	11.6	9.9				
	40 min		114	37.2	19.4	10.1				
	55 min		119	37.4	20.2	10.2				
	1 hr 10 min	Stationary (40 min)	71	37.1	16.9	10.1				
	1 hr 25 min		76	37.0	12.3	10.0				
	1 hr 40 min	Turtleback (40 min)	85	37.0	12.0	9.7				
	1 hr 55 min		106	37.0	10.6	9.2				
	2 hr 10 min		104	37.0	10.1	9.1				
	2 hr 20 min	Exit Pool	106	37.0	9.9	8.0				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 176								
		Grip Strength (psi/sec) = Right 139/74; Left 145/66								
		Shooting (hits/50 targets) = 36								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	83	37.0	22.1	9.9	0	0	0	None
	20 min		76	37.0	19.3	8.3				
	35 min	Skiing (20 min)	86	36.9	16.0	7.3				
	50 min	Seated (10 min)	74	36.8	14.3	7.1				
	1 hr 5 min	Skiing (20 min)								
	1 hr 20 min	Seated (10 min)								
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)								
	15 min	Exit Pool								
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)								
	15 min									
	30 min									
	45 min									
	1 hr	Cognitive SOF PAB (30 min)								
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber								
		Manual Dexterity (sec) = 138								
		Grip Strength (psi/sec) = Right 148/74; Left 140/60								
		Shooting (hits/50 targets) = 35								
		Step Test (# in 60 sec) = 71								
		Pull-Ups (max #) = 21								

\*Subject removed during Phase 3 five minutes early due to low toe temperature.

\*\*The entire exposure was terminated at 50 minutes into phase 6 due to low toe temperature. Low toe temperature was determined to be the result of a slow EKG penetrator leak that eventually soaked both undergarment booties.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			80	36.9	23.6	25.5				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	105	37.0	19.4	23.3	0	200	1	None
	30 min	Stationary (10 min) Climb Caving Ladder	70	37.4	12.6	19.8				
	35 min	Exit Pool	64	37.4	11.9	18.6				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	80	37.4	19.0	16.6	0	0	0	None
	25 min		61	37.4	16.6	14.0				
	40 min		78	37.3	12.4	11.7				
	55 min		62	37.1	11.7	9.8				
	1 hr 10 min		86	37.0	11.2	8.7				
	1 hr 25 min		62	36.9	11.5	7.9*				
	1 hr 40 min									
	1 hr 55 min									
	2 hr	Exit Chamber								
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	109	36.9	10.7	8.7	200	350	1	Chicken&Rice Cheese&Crackers M&Ms
	25 min		102	37.3	10.5	8.6				
	40 min		98	37.5	17.0	8.8				
	55 min		131	37.6	22.5	8.9				
	1 hr 10 min	Stationary (40 min)	90	37.6	21.9	9.0				
	1 hr 25 min		67	37.4	13.8	9.2				
	1 hr 40 min	Turtleback (40 min)	109	37.2	12.6	8.9				
	1 hr 55 min		102	37.4	13.2	8.2				
	2 hr 10 min		103	37.4	13.1	8.2				
	2 hr 20 min	Exit Pool	105	37.5	12.7	8.1				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 156 Grip Strength (psi/sec) = Right 150/48; Left 157/60 Shooting (hits/50 targets) = 32								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	89	37.6	29.6	10.0	250	0	1	None
	20 min		76	37.4	30.4	8.5				
	35 min	Skiing (20 min)	117	37.4	27.9	8.5				
	50 min	Seated (10 min)	110	37.4	27.3	8.9				
	1 hr 5 min	Skiing (20 min)	113	37.5	25.8	9.7				
	1 hr 20 min	Seated (10 min)	106	37.7	25.5	14.5				
	1 hr 30 min	Exit Chamber	71	37.7	25.0	17.1				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	127	37.7	16.5	18.5	0	0	0	None
	15 min	Exit Pool	110	37.8	13.1	19.5				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	66	37.9	27.1	25.9				
	15 min		88	37.8	26.3	26.0				
	30 min		77	37.8	20.2	22.4				
	45 min		56	37.6	17.6	18.4				
	1 hr	Cognitive SOF PAB (30 min)	68	37.5	15.6	15.9				
	1 hr 20 min	Exit Chamber	60	37.3	13.6	11.9				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 175 Grip Strength (psi/sec) = Right 158/75; Left 159/67 Shooting (hits/50 targets) = 34 Step Test (# in 60 sec) = 71 Pull-Ups (max #) = 22								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

\* Subject removed during Phase 3 thirty-five minutes early due to low toe temperature.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			105	37.3	33.1	27.0				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	107	37.8	23.4	19.1	0	0	2	None
	30 min	Stationary (10 min) Climb Caving Ladder	74	37.7	21.0	17.5				
	35 min	Exit Pool	73	37.7	21.0	17.5				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	74	37.6	19.4	20.1	300	0	2	None
	25 min		73	37.5	16.4	18.8				
	40 min		79	37.4	13.4	16.5				
	55 min		72	37.2	11.1	14.8				
	1 hr 10 min		61	37.2	11.0	14.8				
	1 hr 25 min		63	37.2	10.8	15.7				
	1 hr 40 min		65	37.2	10.8	15.7				
	1 hr 55 min		65	37.3	10.1	15.6				
	2 hr	Exit Chamber	93	37.3	10.2	15.4				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	98	37.6	12.1	10.8	300	350	1	Spaghetti Tootsie Roll x 2
	25 min		91	37.8	13.0	13.9				
	40 min		84	37.8	16.3	17.8				
	55 min		109	38.0	18.9	21.5				
	1 hr 10 min	Stationary (40 min)	79	38.0	19.9	21.3				
	1 hr 25 min		75	37.7	18.4	17.8				
	1 hr 40 min	Turtleback (40 min)	80	37.4	16.8	16.5				
	1 hr 55 min		108	37.3	16.5	15.7				
	2 hr 10 min		105	37.4	16.3	13.9				
	2 hr 20 min	Exit Pool	79	37.4	15.9	14.6				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 189 Grip Strength (psi/sec) = Right 160/82; Left 148/83 Shooting (hits/50 targets) = 35								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	72	37.4	17.8	25.2	550	200	2	Chicken Stew Candy
	20 min		65	37.4	14.8	21.7				
	35 min	Skiing (20 min)	117	37.4	14.6	18.8				
	50 min	Seated (10 min)	114	37.5	19.9	21.8				
	1 hr 5 min	Skiing (20 min)	115	37.8	25.0	27.3				
	1 hr 20 min	Seated (10 min)	100	38.0	28.2	30.5				
	1 hr 30 min	Exit Chamber	68	37.9	27.7	32.5				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	91	37.9	26.2	23.8	200	0	0	None
	15 min	Exit Pool	98	37.9	24.7	18.3				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	80	38.0	24.3	24.6	0	0	0	None
	15 min		80	37.9	21.4	25.7				
	30 min		82	37.8	18.2	22.4				
	45 min		72	37.6	14.8	21.6				
	1 hr	Cognitive SOF PAB (30 min)	68	37.4	13.9	20.0				
	1 hr 20 min	Exit Chamber	68	37.3	12.3	18.0				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 161 Grip Strength (psi/sec) = Right 176/106; Left 157/74 Shooting (hits/50 targets) = 39 Step Test (# in 60 sec) = 74 Pull-Ups (max #) = 22								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			78	37.3	34.9	25.6				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	113	37.7	24.1	22.6	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	112	37.9	27.2	20.5				
	35 min	Exit Pool	92	37.9	29.2	NR				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	65	37.5	30.9	21.3	350	200	5	None
	25 min		62	37.5	26.0	18.3				
	40 min		76	37.4	20.3	15.9				
	55 min		78	37.3	17.7	13.8				
	1 hr 10 min		76	37.3	16.1	13.0				
	1 hr 25 min		75	37.3	15.6	12.4				
	1 hr 40 min		85	37.3	15.0	11.8				
	1 hr 55 min		74	37.3	14.9	11.2				
	2 hr	Exit Chamber	NR	NR	NR	NR				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	95	37.3	12.7	12.6	775	450	0	Chicken&Rice
	25 min		92	37.6	12.3	13.1				
	40 min		90	37.8	20.7	14.1				
	55 min		100	37.8	25.6	16.5				
	1 hr 10 min	Stationary (40 min)	80	37.8	22.1	18.6				
	1 hr 25 min		67	37.4	16.6	17.8				
	1 hr 40 min	Turtleback (40 min)	80	37.3	14.1	16.6				
	1 hr 55 min		86	37.3	12.9	16.6				
	2 hr 10 min		97	37.4	12.0	16.8				
	2 hr 20 min	Exit Pool	125	37.4	13.9	17.0				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 207 Grip Strength (psi/sec) = Right 145/84; Left 136/77 Shooting (hits/50 targets) = 42								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	71	37.5	34.1	18.6	250	0	0	Cheese&Crackers
	20 min		106	37.5	32.6	16.7				
	35 min	Skating (20 min)	112	37.4	27.7	16.3				
	50 min	Seated (10 min)	111	37.6	30.5	18.7				
	1 hr 5 min	Skating (20 min)	109	37.8	31.6	21.2				
	1 hr 20 min	Seated (10 min)	108	37.9	33.1	25.8				
	1 hr 30 min	Exit Chamber	73	37.9	34.0	25.8				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	108	37.9	29.8	26.3	0	0	0	None
	15 min	Exit Pool	124	38.0	28.7	26.4				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	82	38.0	31.6	26.4	0	0	1	None
	15 min		79	37.8	33.2	27.5				
	30 min		82	37.7	29.8	25.8				
	45 min		71	37.3	25.3	22.6				
	1 hr	Cognitive SOF PAB (30 min)	64	37.1	21.5	19.2				
	1 hr 20 min	Exit Chamber	82	36.8	19.2	15.9				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 171 Grip Strength (psi/sec) = Right 164/101; Left 136/108 Shooting (hits/50 targets) = 40 Step Test (# in 60 sec) = 74 Pull-Ups (max #) = 22								

30 minute delay between Phase 2 & 3 due to investigation of possible suit leak. No leak found upon inspection, subject continued exposure.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			88	37.6	29.9	23.6				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	116	38.2	19.7	20.3	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	113	38.3	16.8	17.8				
	35 min	Exit Pool	118	38.3	16.2	17.9				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	96	38.3	24.3	17.0	350	400	3	None
	25 min		80	38.2	31.6	14.9				
	40 min		72	37.7	28.7	14.1				
	55 min		78	37.5	22.3	13.2				
	1 hr 10 min		75	37.4	19.8	12.9				
	1 hr 25 min		77	37.3	17.6	12.3				
	1 hr 40 min		84	37.3	16.2	11.7				
	1 hr 55 min		70	37.3	15.6	11.3				
	2 hr	Exit Chamber	109	37.4	15.0	10.9				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	108	37.5	12.7	11.1	525	0	1	Spaghetti Chocolate Bar M&Ms
	25 min		108	37.9	11.9	11.5				
	40 min		108	38.1	19.2	12.1				
	55 min		108	38.1	22.5	12.4				
	1 hr 10 min	Stationary (40 min)	108	37.8	23.1	12.5				
	1 hr 25 min		84	37.5	13.8	11.7				
	1 hr 40 min	Turtleback (40 min)	84	37.1	10.4	10.2				
	1 hr 55 min		108	36.9	14.0	9.5				
	2 hr 10 min		108	37.2	11.7	8.0				
	2 hr 20 min	Exit Pool	108	37.3	13.2	7.2				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 200								
		Grip Strength (psi/sec) = Right 165/80; Left 136/100								
		Shooting (hits/50 targets) = 37								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)								
	20 min									
	35 min	Skiing (20 min)								
	50 min	Seated (10 min)								
	1 hr 5 min	Skiing (20 min)								
	1 hr 20 min	Seated (10 min)								
	1 hr 30 min	Exit Chamber								
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)								
	15 min	Exit Pool								
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)								
	15 min									
	30 min									
	45 min									
	1 hr	Cognitive SOF PAB (30 min)								
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber								
		Manual Dexterity (sec) =								
		Grip Strength (psi/sec) = Right :Left								
		Shooting (hits/50 targets) =								
		Step Test (# in 60 sec) =								
		Pull-Ups (max #) =								

Trek suit got a pinhole leak in the crotch, probably during the caving ladder climb, and subsequently flooded out during phase 4. This caused his toe temperature to reach an abort criteria.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			94	37.2	29.4	34.4				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	96	37.4	19.3	31.5	325	900	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	97	37.3	17.3	30.2				
	35 min	Exit Pool	95	37.4	16.8	29.4				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	88	37.4	23.4	27.1	1,325	300	1	Chicken Stew
	25 min		93	37.3	18.4	23.9				
	40 min		75	37.1	15.8	20.3				
	55 min		87	37.1	14.9	17.2				
	1 hr 10 min		74	36.9	13.9	14.3				
	1 hr 25 min		82	36.9	14.4	13.0				
	1 hr 40 min		83	36.8	14.5	12.2				
	1 hr 55 min		90	36.8	13.7	11.8				
	2 hr	Exit Chamber	NR	NR	NR	NR				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	96	36.8	12.8	13.0	1,375	550	0	Cheese&Crackers
	25 min		108	36.9	11.6	13.1				
	40 min		98	37.1	11.2	13.9				
	55 min		96	37.2	9.8	14.4				
	1 hr 10 min	Stationary (40 min)	78	37.1	13.0	14.4				
	1 hr 25 min		75	37.0	17.0	13.6				
	1 hr 40 min	Turtleback (40 min)	72	36.9	9.6	13.0				
	1 hr 55 min		96	36.9	9.1	12.8				
	2 hr 10 min		96	36.9	15.4	13.2				
	2 hr 20 min	Exit Pool	96	36.9	12.8	13.0				
	PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 153							
		Grip Strength (psi/sec) = Right 145/95; Left 155/79								
		Shooting (hits/50 targets) = 36								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	72	36.9	NR	16.4	550	350	0	Chicken&Rice Peanut Butter&Crackers
	20 min		72	37.1	NR	12.8				
	35 min	Skiing (20 min)	96	36.9	NR	12.2				
	50 min	Seated (10 min)	84	36.8	NR	12.4				
	1 hr 5 min	Skiing (20 min)	96	36.9	NR	11.5				
	1 hr 20 min	Seated (10 min)	90	36.9	NR	10.9				
	1 hr 30 min	Exit Chamber	72	37.0	NR	11.8				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	99	36.9	12.9	13.2	0	0	0	None
	15 min	Exit Pool	98	36.9	10.6	13.0				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	67	37.0	14.6	13.1	0	0	0	None
	15 min		70	37.1	13.1	12.6				
	30 min		93	37.1	13.2	12.0				
	45 min		82	37.1	13.5	11.8				
	1 hr	Cognitive SOF PAB (30 min)	68	37.0	12.4	11.5				
	1 hr 20 min	Exit Chamber	70	36.9	12.1	11.8				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 190								
		Grip Strength (psi/sec) = Right 133/106; Left 115/105								
		Shooting (hits/50 targets) = 34								
		Step Test (# in 60 sec) = 69								
		Pull-Ups (max #) = 25								

Finger temperature readings were inaccurate during Phase 6, secondary to temperature sensor becoming displaced from finger and resting on palm.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			77	36.8	33.4	25.4				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	101	37.1	21.9	24.7	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	94	37.1	17.1	22.4				
	35 min	Exit Pool	95	37.2	19.2	22.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	81	37.3	18.3	20.8	750	850	1	Chicken&Rice
	25 min		81	37.2	16.6	18.4				
	40 min		78	37.0	15.2	16.2				
	55 min		67	36.9	14.7	14.0				
	1 hr 10 min		80	36.7	14.1	13.1				
	1 hr 25 min		71	36.7	15.1	12.2				
	1 hr 40 min		73	36.8	12.9	11.4				
	1 hr 55 min		73	36.8	14.1	10.8				
	2 hr	Exit Chamber	70	36.7	18.2	10.9				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	81	36.7	17.2	11.3	1,550	300	0	Cheese&Crackers
	25 min		96	36.9	12.4	11.0				
	40 min		96	37.1	11.1	11.3				
	55 min		96	37.3	15.1	11.8				
	1 hr 10 min	Stationary (40 min)	81	37.3	20.9	14.8				
	1 hr 25 min		92	37.2	13.7	15.6				
	1 hr 40 min	Turtleback (40 min)	77	37.1	10.5	13.9				
	1 hr 55 min		91	37.1	10.4	13.2				
	2 hr 10 min		89	37.0	10.6	12.1				
	2 hr 20 min	Exit Pool	87	37.0	11.6	12.2				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 190								
		Grip Strength (psi/sec) = Right 136/108; Left 131/94								
		Shooting (hits/50 targets) = 38								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	80	36.8	29.1	14.3	500	250	0	Chicken&Rice
	20 min		69	36.9	26.8	12.9				
	35 min	Skiing (20 min)	77	37.0	22.7	11.2				
	50 min	Seated (10 min)	120	37.0	19.5	12.1				
	1 hr 5 min	Skiing (20 min)	67	37.2	30.2	16.0				
	1 hr 20 min	Seated (10 min)	101	37.3	31.4	15.7				
	1 hr 30 min	Exit Chamber	71	37.4	28.6	15.6				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	96	37.3	24.2	14.8	0	0	0	None
	15 min	Exit Pool	98	37.4	15.6	13.4				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	80	37.4	19.6	13.7	0	0	0	None
	15 min		69	37.4	18.1	12.6				
	30 min		78	37.4	16.3	11.1				
	45 min		74	37.4	15.7	10.2				
	1 hr	Cognitive SOF PAB (30 min)	62	37.3	15.0	9.8				
	1 hr 20 min	Exit Chamber	67	37.1	14.6	9.3				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 261								
		Grip Strength (psi/sec) = Right 142/133; Left 143/103								
		Shooting (hits/50 targets) = 41								
		Step Test (# in 60 sec) = 72								
		Pull-Ups (max #) = 20								

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			84	36.7	32.7	25.2				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	98	36.9	17.9	22.2	0	300	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	85	37.2	14.0	19.9				
	35 min	Exit Pool	98	37.2	13.7	19.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	75	37.2	26.9	17.8	650	0	1	Chicken-ala-King
	25 min		66	37.2	23.4	15.7				
	40 min		74	37.1	18.9	13.5				
	55 min		69	36.9	16.9	11.7				
	1 hr 10 min		63	36.8	13.0	10.8				
	1 hr 25 min		74	36.8	13.1	10.5				
	1 hr 40 min		80	36.7	14.2	10.2				
	1 hr 55 min		74	36.8	13.7	9.9				
	2 hr	Exit Chamber	NR *	NR *	NR *	NR *				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	100	36.9	11.1	10.6	1,375	550	0	Cheese&Crackers
	25 min		97	37.1	12.5	10.4				
	40 min		92	37.2	15.0	10.4				
	55 min		74	37.3	16.6	10.4				
	1 hr 10 min	Stationary (40 min)	82	37.3	15.0	9.9				
	1 hr 25 min		60	37.3	14.1	9.5				
	1 hr 40 min	Turtleback (40 min)	69	37.1	12.9	9.0				
	1 hr 55 min		91	37.1	9.7	12.0				
	2 hr 10 min		111	37.1	11.4	11.1				
	2 hr 20 min	Exit Pool	90	37.1	12.2	10.9				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 168								
		Grip Strength (psi/sec) = Right 145/77; Left 144/69								
		Shooting (hits/50 targets) = 40								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	82	37.2	33.4	15.6	0	0	0	Chilli Mack Peanut Butter&Crackers
	20 min		74	37.2	32.5	14.4				
	35 min	Skiing (20 min)	98	37.1	26.5	12.4				
	50 min	Seated (10 min)	80	37.2	23.1	11.3				
	1 hr 5 min	Skiing (20 min)	88	37.1	19.9	9.8				
	1 hr 20 min	Seated (10 min)	94	37.2	17.0	8.7				
	1 hr 30 min	Exit Chamber	NR	NR	NR	NR				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	101	37.2	14.8	8.9	0	0	0	None
	15 min	Exit Pool	88	37.2	11.9	8.8				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	77	37.1	20.1	10.6	900	0	0	None
	15 min		76	37.1	18.0	9.7				
	30 min		84	37.0	14.9	10.1				
	45 min		79	37.0	13.4	9.8				
	1 hr	Cognitive SOF PAB (30 min)	79	36.9	14.1	9.2				
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber	67	36.9	14.5	11.2				
		Manual Dexterity (sec) = 151								
		Grip Strength (psi/sec) = Right 140/138; Left 159/104								
		Shooting (hits/50 targets) = 39								
		Step Test (# in 60 sec) = 72								
		Pull-Ups (max #) = 25								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

\* No readings taken at the 2 hour mark of Phase 3. Subject transitioned 5 minutes early to extend the interval between test subjects.



PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
<b>PHASE 1</b> Pre-Exposure			99	37.2	19.0	25.8				
<b>PHASE 2 (35 min)</b> Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	127	37.6	27.6	23.8	625	100	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	119	37.6	21.6	23.9				
	35 min	Exit Pool	96	37.7	22.9	23.6				
<b>PHASE 3 (2 hr)</b> Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	93	37.7	26.3	22.9	850	400	2	None
	25 min		99	37.5	29.5	21.6				
	40 min		83	37.3	25.3	19.5				
	55 min		83	37.0	21.5	16.8				
	1 hr 10 min		85	36.9	20.3	15.2				
	1 hr 25 min		86	36.7	16.9	13.7				
	1 hr 40 min		86	36.7	14.0	12.0				
	1 hr 55 min		102	36.8	11.3	10.1				
	2 hr	Exit Chamber	105	36.9	11.1	10.0				
<b>PHASE 4 (2 hr 20 min)</b> Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	111	36.8	17.9	10.7	825	150	1	Chow-Mein Chocolate Cookie Bar
	25 min		122	37.0	14.9	10.7				
	40 min		122	37.6	22.6	10.9				
	55 min		119	37.8	27.3	12.1				
	1 hr 10 min	Stationary (40 min)	105	37.8	27.8	14.1				
	1 hr 25 min		74	37.6	20.4	14.7				
	1 hr 40 min	Turtleback (40 min)	86	37.3	12.9	14.1				
	1 hr 55 min		133	37.2	13.6	13.7				
	2 hr 10 min		118	37.2	12.3	13.6				
	2 hr 20 min	Exit Pool	115	37.8	23.1	13.4				
<b>PHASE 5</b> Exposure Cessation		Manual Dexterity (sec) = 153 Grip Strength (psi/sec) = Right 159/134; Left 173/110 Shooting (hits/50 targets) = 40								
<b>PHASE 6 (1 hr 30 min)</b> Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	NR	NR	NR	NR	0	400	1	None
	20 min		80	37.5	30.8	29.7				
	35 min	Skiing (20 min)	67	37.4	27.8	28.6				
	50 min	Seated (10 min)	125	37.3	22.6	25.1				
	1 hr 5 min	Skiing (20 min)	112	37.4	28.0	24.2				
	1 hr 20 min	Seated (10 min)	104	37.4	30.1	22.2				
	1 hr 30 min	Exit Chamber	68	37.4	30.5	22.0				
<b>PHASE 7 (15 min)</b> Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	107	37.3	23.1	19.9	0	0	0	None
	15 min	Exit Pool	100	37.4	21.3	18.7				
<b>PHASE 8 (1 hr 20 min)</b> Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	70	37.4	20.3	18.6	0	0	0	None
	15 min		66	37.3	17.7	17.3				
	30 min		86	37.2	15.5	15.1				
	45 min		84	37.1	14.4	13.3				
	1 hr	Cognitive SOF PAB (30 min)	66	36.9	13.7	12.3				
<b>PHASE 9</b> Post Exposure	1 hr 20 min	Exit Chamber	57	36.8	14.4	11.4				
		Manual Dexterity (sec) = 235 Grip Strength (psi/sec) = Right 176/132; Left 167/100 Shooting (hits/50 targets) = 35 Step Test (# in 60 sec) = 69 Pull-Ups (max #) = 21								

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			81	36.8	21.0	26.4				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	98	37.0	21.0	24.6	600	0	0	None
	30 min	Stationary (10 min)	71	37.3	18.0	23.7				
	35 min	Climb Caving Ladder Exit Pool	69	37.3	15.8	23.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	78	37.2	16.1	21.6	900	300	0	Chow Mein
	25 min		78	37.0	17.1	17.8				
	40 min		70	36.9	15.0	15.8				
	55 min		67	36.8	14.5	12.6				
	1 hr 10 min		85	36.8	14.6	11.3				
	1 hr 25 min		92	36.8	14.9	10.3				
	1 hr 40 min		86	37.0	15.7	10.1				
	1 hr 55 min		93	37.0	14.7	10.0				
	2 hr	Exit Chamber	NR	NR	NR	NR				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	94	37.2	12.8	10.4	1,500	600	1	Chocolate Brownie
	25 min		98	37.6	23.0	10.7				
	40 min		102	37.7	28.3	11.2				
	55 min		95	37.6	27.9	11.7				
	1 hr 10 min	Stationary (40 min)	85	37.6	21.6	12.6				
	1 hr 25 min		80	37.3	13.7	12.6				
	1 hr 40 min	Turtleback (40 min)	68	37.2	12.8	12.5				
	1 hr 55 min		86	37.1	9.3	12.0				
	2 hr 10 min		103	37.2	12.0	10.9				
	2 hr 20 min	Exit Pool	91	37.4	12.8	10.3				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 144 Grip Strength (psi/sec) = Right 171/69; Left 153/63 Shooting (hits/50 targets) = 36								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	78	37.4	29.2	24.0	0	0	0	None
	20 min		87	37.4	32.3	25.9				
	35 min	Skating (20 min)	113	37.3	24.8	23.2				
	50 min	Seated (10 min)	92	37.6	31.9	23.3				
	1 hr 5 min	Skating (20 min)	109	37.7	30.9	20.7				
	1 hr 20 min	Seated (10 min)	110	37.9	33.1	21.0				
	1 hr 30 min	Exit Chamber	73	37.9	33.4	20.1				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	93	37.7	25.5	18.8	0	200	0	None
	15 min	Exit Pool	91	37.6	21.0	17.9				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	72	37.6	20.5	17.0	325	0	1	None
	15 min		74	37.6	18.4	15.7				
	30 min		78	37.4	18.5	13.4				
	45 min		66	37.3	18.7	12.2				
	1 hr	Cognitive SOF PAB (30 min)	70	37.3	18.1	11.5				
	1 hr 20 min	Exit Chamber	85	37.2	15.4	10.8				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 121 Grip Strength (psi/sec) = Right 190/104; Left 183/69 Shooting (hits/50 targets) = 39 Step Test (# in 60 sec) = 76 Pull-Ups (max #) = 28								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			91	37.2	33.6	30.9				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	103	37.5	19.4	29.0	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	113	37.4	13.0	25.7				
	35 min	Exit Pool	107	37.3	33.2	24.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	89	37.3	32.7	21.7	0	400	2	Chow-Mein Chocolate Bar
	25 min		87	37.1	30.3	20.2				
	40 min		72	37.1	24.0	17.1				
	55 min		83	36.8	18.4	14.7				
	1 hr 10 min		85	36.6	17.3	12.4				
	1 hr 25 min		84	36.7	16.0	11.3				
	1 hr 40 min		84	36.7	14.7	10.7				
	1 hr 55 min		82	36.6	14.6	10.3				
	2 hr	Exit Chamber	84	36.7	14.4	10.0				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	107	36.9	10.7	10.2	1,300	700	2	Pound Cake
	25 min		108	37.2	14.5	10.1				
	40 min		125	37.3	15.7	10.4				
	55 min		121	37.4	16.4	11.2				
	1 hr 10 min	Stationary (40 min)	86	37.3	15.8	13.5				
	1 hr 25 min		94	37.0	12.0	16.2				
	1 hr 40 min	Turtleback (40 min)	86	36.9	10.7	15.8				
	1 hr 55 min		106	37.0	11.9	15.5				
	2 hr 10 min		117	37.4	13.9	13.9				
	2 hr 20 min	Exit Pool	114	37.4	15.2	13.5				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 150 Grip Strength (psi/sec) = Right 159/122; Left 163/76 Shooting (hits/50 targets) = 41								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	87	37.5	35.5	21.3	100	0	0	Ham Slice
	20 min		71	37.4	31.8	19.2				
	35 min	Skiing (20 min)	74	37.4	31.0	18.6				
	50 min	Seated (10 min)	109	37.2	24.2	17.4				
	1 hr 5 min	Skiing (20 min)	64	37.3	20.5	15.0				
	1 hr 20 min	Seated (10 min)	110	37.4	29.6	15.3				
	1 hr 30 min	Exit Chamber	100	37.7	29.4	18.9				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	112	37.6	25.2	18.8	500	0	0	None
	15 min	Exit Pool	101	37.6	21.0	17.3				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	NR	NR	NR	NR	0	0	0	None
	15 min		77	37.6	27.7	13.4				
	30 min		78	37.5	23.3	12.5				
	45 min		91	37.3	18.1	11.8				
	1 hr	Cognitive SOF PAB (30 min)	76	37.2	17.5	9.2				
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber	77	37.1	17.2	7.1				
		Manual Dexterity (sec) = 168 Grip Strength (psi/sec) = Right 163/111; Left 163/103 Shooting (hits/50 targets) = 37 Step Test (# in 60 sec) = 73 Pull-Ups (max #) = 22								

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			86	37.3	32.8	29.3				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	101	37.4	25.7	26.9	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	91	37.6	28.6	26.5				
	35 min	Exit Pool	93	37.6	26.0	26.0				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	78	37.6	21.9	25.0	0	0	0	None
	25 min		71	37.5	16.9	21.7				
	40 min		79	37.4	15.8	17.9				
	55 min		75	37.4	16.0	15.9				
	1 hr 10 min		57	37.3	16.1	13.9				
	1 hr 25 min		68	37.2	14.9	12.4				
	1 hr 40 min		66	37.1	14.0	11.8				
	1 hr 55 min		81	37.1	13.8	11.3				
	2 hr	Exit Chamber	58	37.0	12.9	11.3				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	94	37.2	12.4	12.0	1100	900	1	Chicken&Rice
	25 min		102	37.4	11.1	12.7				
	40 min		103	37.7	11.3	12.7				
	55 min		98	37.9	14.5	13.8				
	1 hr 10 min	Stationary (40 min)	75	37.9	18.6	17.2				
	1 hr 25 min		72	37.7	16.9	17.3				
	1 hr 40 min	Turtleback (40 min)	92	37.7	14.5	16.5				
	1 hr 55 min		78	37.4	13.0	15.6				
	2 hr 10 min		89	37.4	12.2	15.3				
	2 hr 20 min	Exit Pool	110	37.4	11.9	15.1				
		Manual Dexterity (sec) = 217 Grip Strength (psi/sec) = Right 111/66; Left 139/75 Shooting (hits/50 targets) = 33								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	81	37.4	23.8	19.8	0	0	1	None
	20 min		80	37.4	24.1	26.4				
	35 min	Skiing (20 min)	91	37.3	19.8	24.5				
	50 min	Seated (10 min)	93	37.4	16.9	21.1				
	1 hr 5 min	Skiing (20 min)	89	37.4	16.1	18.7				
	1 hr 20 min	Seated (10 min)	76	37.4	15.1	16.2				
	1 hr 30 min	Exit Chamber	78	37.4	15.0	16.0				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	95	37.5	16.0	15.2	800	0	0	None
	15 min	Exit Pool	112	37.6	15.0	15.4				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	93	37.6	27.6	16.4	0	0	0	None
	15 min		97	37.6	25.4	15.4				
	30 min		74	37.7	23.6	13.4				
	45 min		105	37.6	16.8	11.7				
	1 hr	Cognitive SOF PAB (30 min)	75	37.5	15.5	11.7				
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber	63	37.3	16.0	11.1				
		Manual Dexterity (sec) = 175 Grip Strength (psi/sec) = Right 169/69; Left 152/70 Shooting (hits/50 targets) = 39 Step Test (# in 60 sec) = 72 Pull-Ups (max #) = 17								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			92	37.1	35.7	33.9				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	93	37.3	16.9	29.8	0	100	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	70	37.4	16.0	29.0				
	35 min	Exit Pool	70	37.4	13.8	28.7				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	82	37.3	17.0	28.3	0	0	1	None
	25 min		85	37.4	15.1	24.4				
	40 min		75	37.3	14.6	21.2				
	55 min		76	37.3	14.4	17.6				
	1 hr 10 min		79	37.2	13.9	15.6				
	1 hr 25 min		89	37.1	12.8	14.0				
	1 hr 40 min		85	37.2	18.4	12.6				
	1 hr 55 min		83	37.2	19.2	12.4				
	2 hr	Exit Chamber	86	37.2	19.1	12.2				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	91	37.3	13.4	13.4	0	125	0	Chololate Bar Cheese&Crackers Chicken&Rice
	25 min		87	37.4	11.0	13.8				
	40 min		91	37.5	13.2	14.2				
	55 min		89	37.6	14.7	16.6				
	1 hr 10 min	Stationary (40 min)	78	37.6	14.9	17.8				
	1 hr 25 min		76	37.6	10.0	16.7				
	1 hr 40 min	Turtleback (40 min)	98	37.6	9.3	15.9				
	1 hr 55 min		103	37.5	10.2	14.7				
	2 hr 10 min		92	37.6	9.8	14.3				
	2 hr 20 min	Exit Pool	95	37.6	9.6	14.0				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 261 Grip Strength (psi/sec) = Right 143/69; Left 133/69 Shooting (hits/50 targets) = 44								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	78	37.4	34.0	17.0	0	0	0	None
	20 min		84	37.4	32.9	17.2				
	35 min	Skung (20 min)	98	37.4	24.2	15.1				
	50 min	Seated (10 min)	103	37.5	27.8	15.6				
	1 hr 5 min	Skung (20 min)	102	37.6	25.7	16.0				
	1 hr 20 min	Seated (10 min)	88	37.7	28.7	29.4				
	1 hr 30 min	Exit Chamber	74	37.8	29.6	29.1				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	90	37.8	21.6	26.4	900	200	0	None
	15 min	Exit Pool	98	37.8	23.9	25.0				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	90	37.7	26.1	28.3	0	0	0	None
	15 min		87	37.7	28.3	25.4				
	30 min		69	37.7	23.7	22.0				
	45 min		82	37.6	20.0	18.9				
	1 hr	Cognitive SOF PAB (30 min)	71	37.5	18.3	16.3				
	1 hr 20 min	Exit Chamber	89	37.3	16.3	14.3				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 156 Grip Strength (psi/sec) = Right 176/57; Left 148/73 Shooting (hits/50 targets) = 39 Step Test (# in 60 sec) = 72 Pull-Ups (max #) = 16								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			90	37.2	32.9	26.6				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	114	37.5	17.1	22.0	0	200	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	101	37.9	13.5	19.0				
	35 min	Exit Pool	117	37.8	14.3	18.7				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	93	37.9	34.0	17.9	0	0	1	None
	25 min		85	37.9	31.6	14.8				
	40 min		83	37.5	22.9	12.5				
	55 min		96	37.4	19.1	12.0				
	1 hr 10 min		100	37.3	16.0	10.6				
	1 hr 25 min		92	37.1	14.5	10.1				
	1 hr 40 min		80	37.0	14.5	9.5				
	1 hr 55 min		79	37.0	13.5	8.5				
	2 hr	Exit Chamber	87	36.9	13.4	8.5				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	101	36.9	10.2	9.5	700	825	1	Beef Stew
	25 min		112	37.3	9.5	9.9				Cheese&Crackers
	40 min		114	37.6	10.4	10.3				M&Ms
	55 min		115	37.9	12.0	11.5				
	1 hr 10 min	Stationary (40 min)	84	37.7	16.9	16.5				
	1 hr 25 min		75	37.4	11.6	18.9				
	1 hr 40 min	Turtleback (40 min)	74	37.3	8.7	17.3				
	1 hr 55 min		113	37.2	9.5	16.8				
	2 hr 10 min		110	37.5	11.5	18.5				
	2 hr 20 min	Exit Pool	120	37.7	14.3	20.2				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 185								
		Grip Strength (psi/sec) = Right 154/61; Left 153/71								
		Shooting (hits/50 targets) = 39								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	87	37.7	35.5	31.0	0	0	0	None
	20 min		90	37.6	35.6	31.9				
	35 min	Skiing (20 min)	138	37.5	29.1	29.3				
	50 min	Seated (10 min)	80	37.4	34.0	11.7				
	1 hr 5 min	Skiing (20 min)	115	37.8	32.0	32.0				
	1 hr 20 min	Seated (10 min)	105	37.8	33.6	32.3				
	1 hr 30 min	Exit Chamber	105	37.8	33.6	32.3				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	111	37.6	22.7	28.4	0	0	0	None
	15 min	Exit Pool	117	37.7	18.5	26.2				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	96	37.8	30.4	26.7	0	0	0	None
	15 min		107	37.8	25.8	22.7				
	30 min		95	37.7	23.2	20.3				
	45 min		101	37.6	18.5	16.1				
	1 hr	Cognitive SOF PAB (30 min)	80	37.4	14.9	13.3				
PHASE 9 Post Exposure	1 hr 20 min	Exit Chamber	76	37.1	13.2	11.1				
		Manual Dexterity (sec) = 187								
		Grip Strength (psi/sec) = Right 161/67; Left 135/61								
		Shooting (hits/50 targets) = 37								
		Step Test (# in 60 sec) = 72								
		Pull-Ups (max #) = 15								

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			80	37.5	24.7	24.2				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	105	37.6	17.6	21.7	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	143	37.9	15.6	20.5				
	35 min	Exit Pool	114	38.0	14.7	20.1				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	67	38.0	30.6	19.8	500	300	1	None
	25 min		75	37.8	28.4	17.4				
	40 min		82	37.7	23.3	16.0				
	55 min		84	37.5	18.5	14.1				
	1 hr 10 min		66	37.2	17.8	13.4				
	1 hr 25 min		75	37.1	16.6	12.3				
	1 hr 40 min		58	37.0	15.7	12.2				
	1 hr 55 min		55	37.0	15.0	11.8				
	2 hr	Exit Chamber	70	37.0	15.0	11.6				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	108	37.1	11.9	13.3	825	50	1	Escalloped Potatoes&t Pound Cake
	25 min		108	37.4	18.5	13.8				
	40 min		104	37.6	14.5	25.4				
	55 min		104	37.8	15.8	28.7				
	1 hr 10 min	Stationary (40 min)	96	37.8	16.9	27.4				
	1 hr 25 min		94	37.4	18.0	24.4				
	1 hr 40 min	Turtleback (40 min)	94	37.4	15.0	22.5				
	1 hr 55 min		108	37.4	12.6	20.8				
	2 hr 10 min		96	37.5	12.7	19.9				
	2 hr 20 min	Exit Pool	97	37.7	12.3	19.0				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 139								
		Grip Strength (psi/sec) = Right 183/64; Left 188/68								
		Shooting (hits/50 targets) = 39								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	72	37.5	28.8	20.0	400	0	0	None
	20 min		72	37.6	30.5	18.1				
	35 min	Skiing (20 min)	100	37.4	25.2	16.2				
	50 min	Seated (10 min)	102	37.5	22.4	16.8				
	1 hr 5 min	Skiing (20 min)	96	37.6	21.2	15.7				
	1 hr 20 min	Seated (10 min)	96	37.8	21.6	17.2				
	1 hr 30 min	Exit Chamber	72	37.8	25.0	16.7				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	96	37.7	19.8	15.4	0	0	0	None
	15 min	Exit Pool	99	37.8	15.8	14.8				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	84	37.8	25.9	15.4	250	100	1	None
	15 min		84	37.6	30.3	14.6				
	30 min		80	37.6	25.2	12.6				
	45 min		85	37.5	19.5	11.1				
	1 hr	Cognitive SOF PAB (30 min)	74	37.4	17.9	10.9				
	1 hr 20 min	Exit Chamber	75	37.1	16.7	10.4				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 151								
		Grip Strength (psi/sec) = Right 186/72; Left 181/73								
		Shooting (hits/50 targets) = 36								
		Step Test (# in 60 sec) = 63								
		Pull-Ups (max #) = 19								

PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			80	36.9	26.2	31.2				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	96	37.1	24.7	22.7	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	72	37.2	23.7	20.1				
	35 min	Exit Pool	79	37.2	23.3	19.4				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	75	37.2	22.6	19.4	0	0	1	None
	25 min		63	37.3	20.0	18.0				
	40 min		60	37.2	18.0	17.8				
	55 min		78	37.1	16.1	16.0				
	1 hr 10 min		63	36.9	14.4	14.6				
	1 hr 25 min		69	36.8	13.6	14.4				
	1 hr 40 min		61	36.8	12.4	14.2				
	1 hr 55 min		75	36.8	12.2	13.2				
	2 hr	Exit Chamber	86	36.8	12.1	13.1				
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	85	36.6	13.7	14.7	1,100	200	0	Omelet Chocolate Cookie Bar M&Ms
	25 min		88	36.9	14.6	13.2				
	40 min		98	37.2	15.6	13.5				
	55 min		91	37.2	17.2	14.4				
	1 hr 10 min	Stationary (40 min)	81	37.2	18.0	21.0				
	1 hr 25 min		60	37.1	17.3	18.9				
	1 hr 40 min	Turtleback (40 min)	91	36.9	16.2	15.0				
	1 hr 55 min		103	36.9	15.1	14.8				
	2 hr 10 min		NR*	NR*	NR*	NR*				
	2 hr 20 min	Exit Pool	NR*	NR*	NR*	NR*				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 148 Grip Strength (psi/sec) = Right 186/65; Left 186/59 Shooting (hits/50 targets) = 29								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	62	37.2	16.0	25.4	0	0	0	None
	20 min		74	37.1	15.1	25.1				
	35 min	Skiing (20 min)	93	36.9	15.1	25.3				
	50 min	Seated (10 min)	100	37.3	17.0	24.1				
	1 hr 5 min	Skiing (20 min)	105	37.5	18.8	22.9				
	1 hr 20 min	Seated (10 min)	93	37.7	23.6	21.4				
	1 hr 30 min	Exit Chamber	79	37.7	24.3	19.8				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	84	37.6	23.9	14.8	0	0	1	None
	15 min	Exit Pool	88	37.5	22.5	13.0				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	73	37.5	21.0	17.7	250	0	0	None
	15 min		75	37.5	19.1	17.3				
	30 min		76	37.5	16.9	16.5				
	45 min		71	37.4	15.5	16.1				
	1 hr	Cognitive SOF PAB (30 min)	81	37.4	15.2	15.7				
	1 hr 20 min	Exit Chamber	68	37.1	14.0	16.2				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 135 Grip Strength (psi/sec) = Right 179/69; Left 192/70 Shooting (hits/50 targets) = 37 Step Test (# in 60 sec) = 66 Pull-Ups (max #) = 20								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

\* Wrist seals were too tight/constricting blood flow; therefore, drysuit wrist seals were trimmed during this period.



PHASE (total exposure time)	ELAPSED TIME	TASKS PERFORMED	INSTRUMENT READINGS				I/O			
			HR (bpm)	CORE (deg C)	FINGER (deg C)	TOE (deg C)	VOID (cc)	H2O (cc)	Carb-BOOM (140g) + 50cc H2O	MREs
PHASE 1 Pre-Exposure			75	36.0	22.0	23.5				
PHASE 2 (35 min) Pool Exposure (1st Iteration)	15 min	2 Breath Hold Descents Turtleback (15 min)	100	36.8	16.8	20.0	0	0	0	None
	30 min	Stationary (10 min) Climb Caving Ladder	79	36.9	15.8	17.6 *				
	35 min	Exit Pool	76	36.9	15.2	17.2				
PHASE 3 (2 hr) Environ. Chamber (1st Iteration)	10 min	Stationary (2 hr)	59	37.8	24.2	16.6	580	0	1	None
	25 min		58	36.8	23.8	14.4				
	40 min		64	36.8	20.0	12.0				
	55 min		53	36.6	18.8	10.8 **				
	1 hr 10 min		57	36.2	17.2	9.2 **				
	1 hr 25 min		61	36.2	16.4	8.8 **				
	1 hr 40 min									
	1 hr 55 min									
	2 hr	Exit Chamber								
PHASE 4 (2 hr 20 min) Pool Exposure (2nd Iteration)	10 min	Turtleback (1 hr)	87	36.0	15.8	9.8	0	1,000	0	Chicken Stew Chocolate Nut Cake Tootsie Roll x 2
	25 min		92	36.2	12.4	10.4				
	40 min		87	36.2	13.0	11.0				
	55 min		78	36.4	13.2	11.8				
	1 hr 10 min	Stationary (40 min)	63	36.4	16.2	11.8				
	1 hr 25 min		70	36.4	17.5	11.5				
	1 hr 40 min	Turtleback (40 min)	87	36.2	16.0	11.0				
	1 hr 55 min		73	36.2	16.0	11.0				
	2 hr 10 min		96	36.2	18.6	13.0				
	2 hr 20 min	Exit Pool	96	36.8	18.0	12.8				
PHASE 5 Exposure Cessation		Manual Dexterity (sec) = 149 Grip Strength (psi/sec) = Right 193/72; Left 193/62 Shooting (hits/50 targets) = 31								
PHASE 6 (1 hr 30 min) Environ. Chamber (2nd Iteration)	5 min	Cognitive SOF PAB (30 min)	75	36.8	31.0	24.0	0	0	1	None
	20 min		67	36.8	27.8	23.0				
	35 min	Skating (20 min)	107	36.8	25.8	20.6				
	50 min	Seated (10 min)	101	37.0	27.5	19.9				
	1 hr 5 min	Skating (20 min)	101	37.0	26.2	13.2				
	1 hr 20 min	Seated (10 min)	103	37.2	27.4	20.2				
	1 hr 30 min	Exit Chamber	66	37.2	27.2	19.8				
PHASE 7 (15 min) Pool Exposure (3rd Iteration)	5 min	Turtleback (10 min)	95	37.2	27.0	17.6	0	0	0	None
	15 min	Exit Pool	99	37.0	22.8	16.8				
PHASE 8 (1 hr 20 min) Environ. Chamber (3rd Iteration)	5 min	Stationary (50 min)	84 ***	37 ***	29.8 ***	12 ***	400	0	0	None
	15 min		70 ***	37.1 ***	31.9 ***	15.7 ***				
	30 min		80	37.0	29.8	13.8				
	45 min		78	37.0	26.2	12.0				
	1 hr	Cognitive SOF PAB (30 min)	64	37.0	22.2	12.0				
	1 hr 20 min	Exit Chamber	70	36.8	21.0	11.8				
PHASE 9 Post Exposure		Manual Dexterity (sec) = 155 Grip Strength (psi/sec) = Right 179/71; Left 177/69 Shooting (hits/50 targets) = 36 Step Test (# in 60 sec) = Omitted due to blood flow restriction of feet. Pull-Ups (max #) = 19								

Phase 2 caving ladder climb was omitted for the remainder of the study due to the potential for suit damage which would result in premature termination of the exposure routine.

\* 30 minutes into Phase 2, subject reported foot discomfort. This was attributed to the narrow width of the Trek integral boot.

\*\* 1 hour into Phase 3, subject reported extreme foot discomfort. The decline in toe temperature over the next 2 readings was determined to be the result of restricted blood flow due to foot confinement. Phase 3 exposure was terminated at 1 hour and 26 minutes, and subject transitioned to Phase 4.

\*\*\* The chamber fan was off for the first 26 minutes of this subject's Phase 8 exposure (while test subject B completed his Phase 6 exposure). Therefore the room was at an ambient temperature of -10 deg C, vice the prescribed wind chill effect of -21 deg C.